FINAL REPORT

PRODUCTION ENGINEERING PROGRAM

TO DEVELOP IMPROVED MASS-PRODUCTION PROCESS

FOR

M42/M46 GRENADE BODIES

Prepared For: Commander
U.S. Army Armament Research and Development Command
Large Caliber Weapons Systems Lab,
Submunitions Section (DRDAR-LCU-DS)
Mr. Joe Manna
Dover, New Jersey 07801

Contract: DAAK10-77-C-0050

March, 1978

DAYRON CORPORATION
ORLANDO, FLORIDA

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FOREWORD

This report describes the work performed by Dayron Corporation under Contract DAAK10-77-C-0050 for the development of a new process for manufacturing M42/M46 grenade bodies at reduced cost without jeopardizing munition effectiveness, safety or reliability.

The present M42/M46 grenade body fabrication technique; a blank, cup and draw process, was at the threshold of the state-of-the-art when it was selected some years ago. It has been developed and refined over the years such that it is capable today of producing a most demanding product in very high volume to exacting quality requirements. Without question, it is a successful process. Its main drawback is that it is a relatively expensive process and will likely remain so. A secondary disadvantage is the inherent tendency of this blank, cup and draw technique to produce "smiles" or cracks which necessitate costly trimming and significant inspection to maintain requisite quality standards.

Since the selection of the blank, cup and draw process was made, there have been most significant advances in the state-of-the-art of alloy steel tube fabrication techniques. Today it is routine to manufacture accurately welded tubing using molybdenum steel alloys which was not possible a few years ago. Dayron opted to take advantage of these modern techniques to

fabricate the tube portion of the grenade body. The dome would be separately produced and the two elements would be joined to form the complete unit.

Various designs and processes were investigated for the fabrication of a two-piece grenade body assembly consisting of a dome attached to a cylinder. Numerous techniques were initially reviewed and culled. Such candidate processes as laser-beam welding, electron-beam welding and mechanical crimping were evaluated and eliminated from consideration in favor of more promising techniques which are discussed herein. The following processes were investigated in depth:

CYLINDER FABRICATION

- Cylinders made from welded tubing (embossed material)
- Cylinders made from seamless mechanical tubing
- Embossed fragment pattern knurled by special machine into inside of seamless mechanical tubing
- Punch press-formed cylinders with laser/electron beam-welded joint

DOME FABRICATION

- Domes made by transfer press/transfer die (embossed material)

JOINING CYLINDER AND DOME

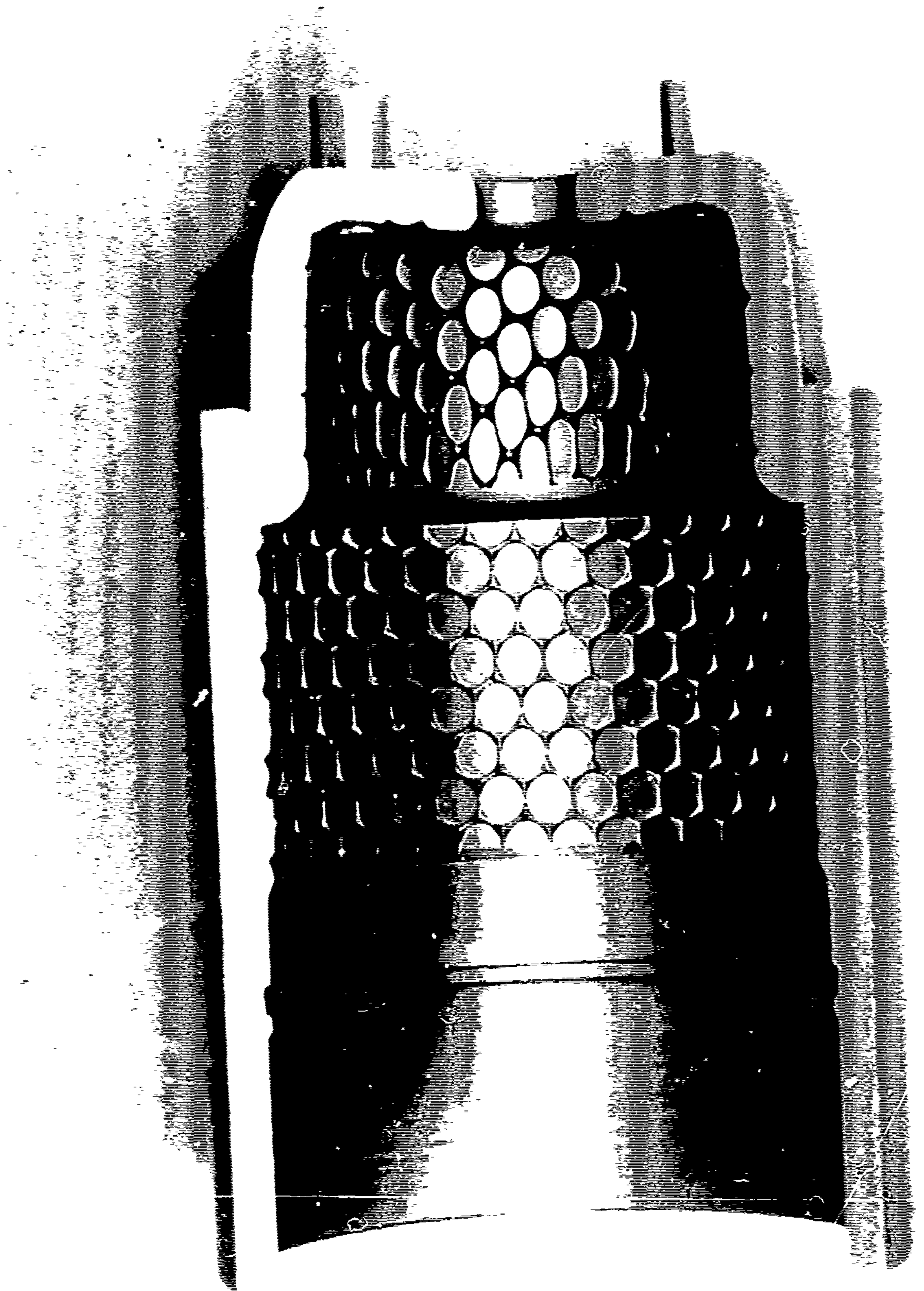
- Dome/cylinder attachment by inertia welding
- Dome/cylinder attachment by furnace brazing

RESULTS

The optimum design and process were found to be a two-piece assembly consisting of a cylinder fabricated from embossed 4140 steel in a tube mill and attached by furnace brazing to an embossed dome fabricated in a transfer press. This grenade body assembly easily passed all M42 grenade requirements. Tests indicate that with optimum process development, it will also pass the M46 grenade requirements. This achievement will eliminate the need for M46 grenades. Photograph Number 1 on the following page illustrates the final two-piece configuration. Note the undistorted fragmentation pattern obtained with the tube-mill weldment.

The projected high-volume production cost for the new two-piece grenade is about one-third less than the realistically projected cost of the current configuration. .se we believe the two-piece configuration to be a superior product capable of being produced at a substantially lower cost, we recommend that a follow-on engineering development program be promptly initiated to produce and test 50,000 two-piece grenade bodies.

When it is evident during the follow-on program that the new process is successful and superior to the present process, we also recommend that an initial production capability be commenced to fully prove out the process and to determine the economic practicality of converting the current six producers to the new process.



(Photograph 1) M42 GRENADE BODY BRAZED ASSEMBLY

1. INTRODUCTION

The M483A1 155MM projectile and M509 eight-inch round are submissiled munitions. The M483A1 is used with the self-propelled M109A Howitzer. The M483A1 contains M42 and M46 grenades while the M509 round contains M42 grenades only. The M42 and M46 grenades are submunitions approximately 1.5 inches in diameter and 3 inches in length, each consisting of a body assembly, an M223 fuze and a tape stiffener assembly.

The body assembly for each of the two submunitions is different in that the M46 grenade is smooth-walled and the M42 grenade has an embossed inner surface. The grenades must be strong enough to withstand extraordinary longitudinal and transverse forces experienced during projectile launch. The manufacturing method for the body now used and proposed for use in plants as they come on-stream has its foundation in deep drawing a cup from cold rolled strip stock (embossed for the M42 body) with intermediate annealing operations followed by ancillary machining, heat-treating, protective finishing and inspection steps. This process, particularly the deep draw, generates large amounts of scrap. Further, the drawing operation inherently produces "smiles" or cracks in the grenade body walls necessitating very close inspection, including ultrasonic final inspection to assure a quality

product. The cost of using the existing process is so great that exploration of more efficient processes is mandated for the projected extremely high production quantities of these grenades. The improved process recommended herein not only produces a superior product, but results in significant projected cost savings as compared with the current blank, cup and draw technique.

Dayron has been successful in developing a two-piece assembly which will more than satisfy the desired technical requirements. This assembly consists of a cylinder and a dome copper-brazed together. The following discussion will describe and relate all the work and investigations performed in obtaining this optimum grenade body design.

2. DISCUSSION

2.1 Cylinder Development

Various methods of obtaining a cylinder of the desired physical and dimensional requirements were initially considered. It was decided that the following three processes would receive in-depth study and investigation:

I. Emboss coiled 4140 steel flat stock in a Fenn mill to give the desired standard M42 grenade fragment pattern and then form the coiled stock into a tube and weld it in one continuous operation. The resulting tube would then be cut into the proper cylinder lengths.

II. Purchase commercially made seamless mechanical 4140 steel tubing and cut it into the appropriate cylinder lengths for M46 grenades. For M42 grenades, the cylinders would have a fragmentation pattern knurled into the inside diameter by a special machine.

III. Emboss coiled 4140 steel stock in a Fenn mill to give the desired standard M42 fragmentation pattern and then feed the coiled stock into a progressive punch press die that would stamp and form the coil into a cylinder. The seam would later be welded by laser or electron beam. M46 cylinders would be fabricated from nonembossed material.

The above three techniques for cylinder fabrication are next discussed in detail:

2.1.1 Welded Tubing

Approximately twenty (20) of the most respected tube welding companies in the United States were contacted and tubing requirements discussed with them. It was decided that three (3) had the expertise to be successful in fabricating a tube in 4140 steel to the required dimensional and physical specifications. These companies were:

- Babcock & Wilcox, Alliance, Ohio
- True Temper, Geneva, Ohio
- Metalmatic, Minneapolis, Minnesota

Babcock & Wilcox was awarded a contract by Dayron because of their in-depth experience in successfully producing various alloy steel tubing. The contract was to fabricate and deliver 650 feet of embossed, 4140 alloy steel, welded tubing to our specifications.

The 4140 material was obtained from the Sharon Steel Company, Sharon, Pennsylvania, and sent to Amron Corporation, Waukesha, Wisconsin, for embossing. The material was annealed after embossing and was then shipped to Ohio Steel Slitters, Canton, Ohio, to have the 7.825" wide by .119" thick material slit to 4.830" + .020" width. The slit material was then shipped to Babcock & Wilcox for tube fabrication. The remaining material at Ohio Steel Slitters was shipped to Kratz-Wilde Company to be fabricated into domes.

Babcock & Wilcox produced the tubing using the following continuous operations:

- Place coiled material on tube fabrication line.
- Slit material to final width.
- Form into tubing (Abney-Etna Tube Mill).
- Weld seam (Therma-Tool High Frequency Welder).
- Ultrasonic inspection.
- Trim weld (outside and inside).
- Cut to length (24 feet).
- Conveyor transfer to full anneal furnace at 1300°F.
- Straighten tubing.
- Eddy-current inspection for cracks, voids, weld and overall material integrity per ASTM 513-76.
- Oil, pack and ship.

The tubing was inspected at Dayron for dimensional characteristics. The outside diameter varied from 1.513" to 1.511", well within the Government print requirements of 1.524" - 1.509". The wall thickness measured .120" which was less than anticipated. The coil material measured .119" before tube-forming. The wall thickness will increase as the material is formed from a flat to a round configuration during the fabrication of smooth-walled tubing. Because of the embossing in the inside, the wall thickness did not increase as much

as expected; therefore, the inside diameter measured 1.274" instead of the desired 1.254". This undersize wall thickness condition will reduce the transverse strength of the finished grenade body, but should not affect longitudinal strength as failure in this mode occurs in the machined area near the open end.

The hardness of the tubing as received measured Rockwell "A" Scale 64 which is a little harder than optimum for machinability. Babcock & Wilcox stated that the hardness can be reduced during the fabrication operation should we so desire.

As evidenced by tests and inspections made by Dayron, the tubing material as supplied is very consistent in physical and dimensional characteristics and can be used directly as received for M42 grenade body production.

2.1.2 Seamless Mechanical Tubing

Several companies that specialize in manufacturing seamless mechanical tubing in alloy steels were contacted. After careful consideration, Quanex Corporation (Michigan Seamless Tube Company) of South Lyon, Michigan, was given a purchase order to fabricate 250 feet of soft annealed 4140 steel seamless tubing to the following dimensions:

Outside Diameter	(inches)	1.517 + .007 - .002
Inside Diameter	(inches)	1.258 + .002 - .007
Wall Thickness	(inches)	.130 + .010 - .010

The diameters of the received material were very consistent, measuring between 1.521" and 1.523" on the outside and 1.256" to 1.258" on the inside. This close control was very impressive. The wall thickness, however, varied from .122" to .140" for a total .018" variation. Because of this variation, the material could not be successfully used for fabricating M46 cylinders because after machining the inside diameter to meet concentricity requirements, the resultant inside diameter measured approximately 1.275" (.015" oversize). The maximum inside diameter on the Government drawing is 1.260".

Ordering new material to different dimensions was considered. However, the embossed welded tubing from the tube mill was at that time already evidently successful. It was therefore decided not to perform additional work on seamless mechanical tubing, but to fully concentrate our investigation on the welded tubing.

The unit cost of each grenade body candidate, welded versus seamless, is nearly identical. However, the inside diameter of the welded tubing does not require a machining operation to meet print requirements. This factor means that more scrap and labor is expended in fabricating grenade bodies from seamless tubing which further supported our conclusion to devote all of our attention to the welded-cylinder approach.

The hardness of the received seamless tubing was Rockwell "A" 52 and machined in an acceptable manner. Transverse and longitudinal tests of heat-treated sample seamless grenade cylinders showed very good strength. Seamless mechanical tubing could be successfully used in fabricating a two-piece M46 grenade body assembly should the preferred welded tubing approach later prove to be unsatisfactory.

2.1.2.1 Seamless Mechanical Tubing With Internal Knurled Fragment Pattern

In order to produce an M42 grenade body from seamless mechanical tubing, it is necessary to cut or form a shrapnel pattern into the inside diameter of the

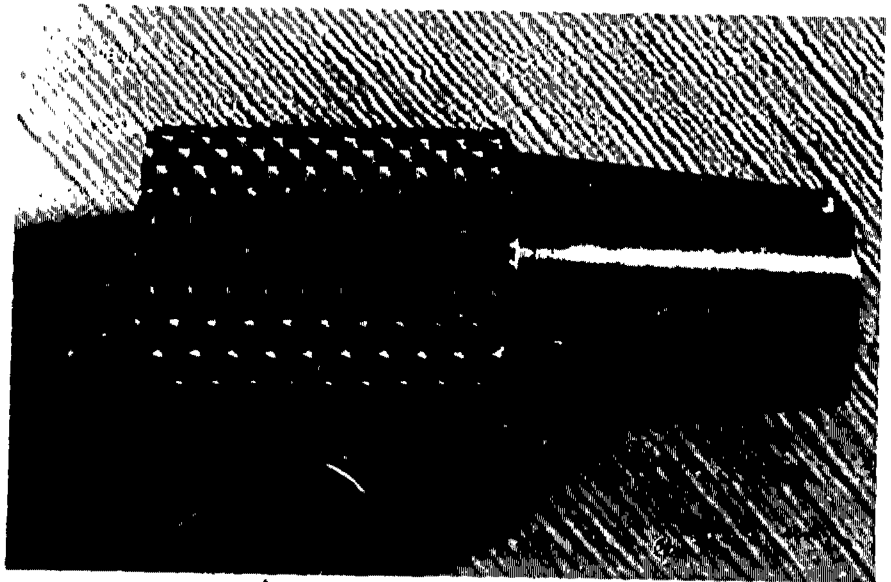
cylinder. High-speed knurling and thread-forming on exterior surfaces are very well-developed and successful techniques. Because of these economical and accepted practices, Dayron proposed to perform tests to determine the feasibility of knurling the required shrapnel pattern on the inside of a cylinder.

Several leading companies that design and build thread-rolling equipment were contacted. A contract was awarded to Tesker Manufacturing Corporation, Saukville, Wisconsin, to develop a process to knurl the desired internal pattern. Tesker Manufacturing was unable to fabricate a successful knurling tool. Dayron then contacted Roehlen Engraving Company, Rochester, New York, the current supplier of M42 grenade body Fenn mill embossing rolls. Roehlen was awarded a contract and fabricated a knurling tool for use in the modified Tesker thread-rolling machine. This tool reproduces exactly the currently accepted M42 grenade body pattern. (See Photograph Number 2.)

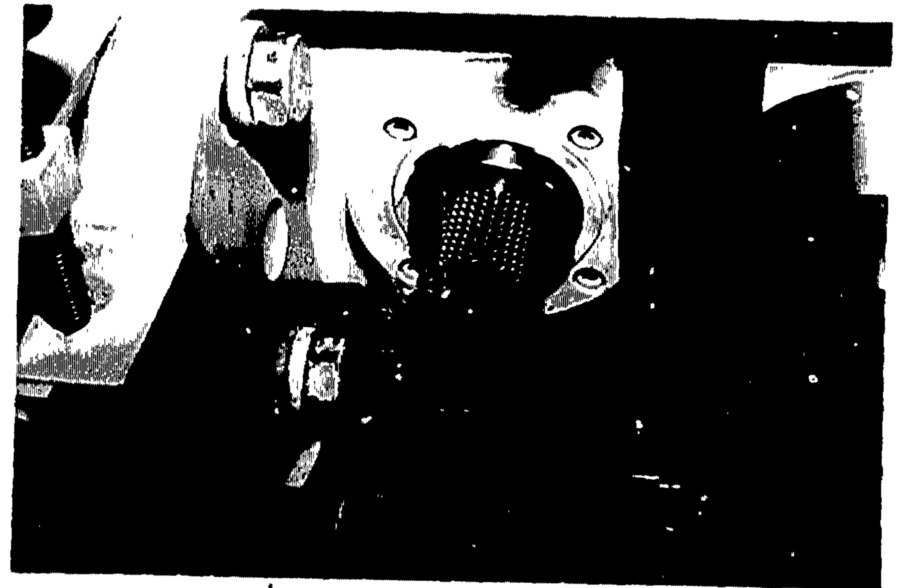
Cylinders of 4140 steel were cut from bar stock for use in the process development. The tooling was installed (see Photograph Number 3) and process tests performed. Very light knurling pressure was used on the first samples. The pressure was gradually increased until a pattern depth of .007" was achieved. It became apparent at that time that a full depth of .015" to .020" could not be obtained without sacrificing other dimensional requirements. Using 9,000 pounds of roller pressure to force the knurling tool .007" into the annealed 4140 steel caused the outside diameter of the cylinder to increase in size by .036" to .042" and also caused an out-of-round condition of .015" T.I.R.

It was also noted that several revolutions of the machine were needed to obtain the .007" depth and that each time the cylinder revolved, the teeth in the knurling tool would not accurately line up with the pattern formed on the previous revolution. As the pressure was increased to obtain more pattern depth, the cylinder inside diameter also increased, causing further misalignment. The end result was unsatisfactory.

It is conceivable that by developing a highly refined cylinder blank to compensate for the process environments, an internal knurling process might be successful. However, with the concurrently successful embossed welded tubing technique, it was decided to suspend further work on the knurling approach. The tooling and equipment used to conduct the above tests are shown on the following page.

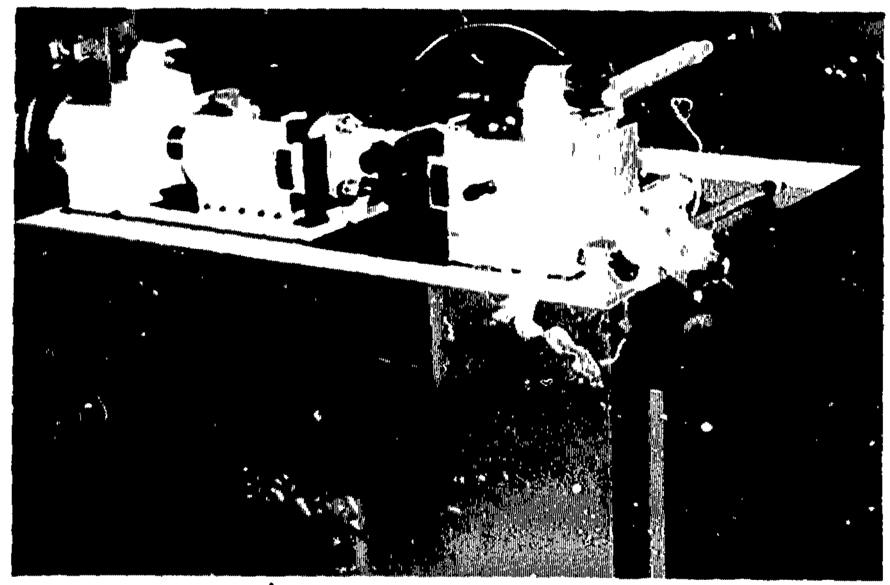


(Photograph 2) KNURLING TOOL



(Photograph 3) KNURLING TOOL INSTALLED IN MACHINE

(Photograph 4) SHRAPNEL PATTERN BEING KNURLED INTO M42 GRENADE CYLINDER



(Photograph 5) MODIFIED THREAD-ROLLING MACHINE TO EMBOSS SHRAPNEL PATTERN INTO M42 GRENADE BODY CYLINDER

2.1.3 Punch Press-Formed Cylinder, Laser/Electron Beam Welded Joint

This third concept for cylinder manufacture consisted of feeding embossed (M42) or nonembossed (M46) material into a punch press progressive die and producing a cylinder in a series of blanking, trimming and forming operations. The cylinder would then be fed into an automatic laser or electron beam welding machine to weld the cylinder seam closed.

Fifteen (15) companies with extensive experience in punch press tooling design were contacted. The following three companies were visited:

- Harig Manufacturing Company, Chicago, Illinois
- Weatherby Tool Company, Jacksonville, Florida
- Wright Manufacturing Company, Nashville, Tennessee

After much study and consultation with these people, it was concluded that fabricating a cylinder with a seam capable of being laser or electron beam welded would require exceedingly complex and expensive tooling which would be impracticable to maintain with production at rates of 1,400,000 units per month.

The reason for such difficulty is that the optimum joint configuration for welding is a surface-to-surface contact. A maximum of only a .005" space between surfaces can be tolerated in order to assure a reliable welded joint. The requisite degree of alignment and joint preparation to achieve such parallelism is considered beyond the state-of-the-art to achieve in a punch press-developed cylinder.

The three tool companies all indicated that the total forming and welding operation optimumly should be performed automatically in a tube mill. Based upon the information received and the unsatisfactory sample parts obtained during our investigation, Dayron concluded that the punch press process for cylinder fabrication was not economically feasible.

2.2 Dome Development

As stated earlier, Dayron's approach to fabricating an economical and reliable M42/M46 grenade body consists of attaching a dome to a cylinder. Fabrication of the dome will be accomplished in a transfer press using embossed (M42) or nonembossed (M46) coil stock. Details concerning this process follow:

2.2.1 Transfer Press/Transfer Die

The Waterbury Farrel Division of Textron, Inc., Cheshire, Connecticut, was contacted early in the program because of their expertise in developing tooling for the blank, cup and draw method now being used to manufacture M42/M46 grenade bodies. Because of Waterbury's commitments to other programs, they were unable to accept a timely dome development contract from Dayron. After an extensive industry search, a contract was awarded to Kratz-Wilde Machine Company, Covington, Kentucky, to develop a transfer-press process to produce a dome that could be used on both M42 and M46 grenade bodies.

Two dome designs were submitted to Kratz-Wilde; one to be used for a brazed assembly (Drawing Number 9327238) and one to be used in conjunction with an inertia-welded assembly. (See Figure Number 1.)

In order to provide a dome that contained the desired fragmentation pattern used in the M42 grenade, it was necessary to begin the operation with embossed coil stock and then form

that material into a dome. Embossed 4140 steel coil stock containing the current M42 shrapnel pattern was obtained from Amron Corporation, Waukesha, Wisconsin.

Kratz-Wilde was successful in developing the tooling and fabricating domes to Drawing Number 9327238 (Brazed Assembly Design). Their process required four (4) separate dies representative of either a transfer press operation or transfer die operation. Approximately 1,000 domes were produced to this configuration. The two .125" diameter holes and one .209" diameter center hole were not included in these initial dies, but would be incorporated in the final high-production tooling necessary to meet the 1,400,000 unit-per-month anticipated production rate.

Material width to be used in the high-production tooling would be 5.192", die progression 2.160" and material thickness .119". This press operation will yield three (3) dome blanks/progression. The formed parts as received required a machining operation to form the .045" + .020" radius at the inside open end and a facing operation to meet the .005" perpendicularity requirement.

In high production, the .045" radius would be incorporated in the forming tooling and the .005" perpendicularity requirement would be accomplished with a Blanchard automatic grinding machine.

Kratz-Wilde was not successful in developing tooling to produce domes to the inertia-welded assembly design. (See Figure Number 1.) The embossed material fractured and peeled up from the pattern grooves when any attempt was made to form the material with the embossing on an outside radius. However, solid material could be successfully formed for M46 grenade domes. Based upon this peeling problem which would have been costly and time-consuming to solve, it was decided to forego further work in developing a press part for the inertia-welded design. Parts used for inertia-welded assemblies were later machined from bar stock in the evaluation of the inertia-welding technique which is discussed in the following pages.

2.3 Joining the Cylinder and Dome

Of the many assembly processes initially evaluated, Dayron elected to concentrate on the development of two techniques which appeared most promising to attach the dome to the cylinder. The two assembly methods were brazing and inertia welding. First we shall discuss inertia welding.

2.3.1 Inertia-Welded Assembly

Inertia welding is a unique form of friction welding which utilizes kinetic energy stored in a flywheel system for all of the needed heating and much of the required forging.

One workpiece is fixed in a stationary holding device. (See Photograph Number 7.) The other, clamped in a spindle chuck (see Photograph Number 8) usually with attached flywheel, is spun up rapidly. At a predetermined RPM, driving power is cut and the fixed part is thrust against the rotating part. Friction between the parts decelerates the flywheel, converting stored energy to frictional heat -- enough to soften, but not melt the contacting surfaces of the parts. The energy level is established to be sufficient to achieve forging temperatures. The rate of energy consumption is determined by the weld itself. When the energy is fully consumed, the weld is completed and flywheel rotation stops.

Inertia welding has many advantages over other metal-joining processes. Some of these advantages are as follows:

- After initial setup, it is a machine-controlled process with no subjective human skills involved.

- No external heat is applied. Only the frictional heat generated by the two pieces and thrust pressure is used.

- There are no special conditions required -- no separate location, no oxygen or gas, no glare shielding or splatter protection, no ventilation. The process is compatible with other machines in a production line.

- There is no flux or filler metal required for the process.

- Normally there is no special preparation required of the contacting part surfaces. They can be inertia welded directly from previous processing, whether cast, forged, saw-cut or sheared.

- The bond itself is a forging, characterized by a fine grain structure. It is free of impurities and voids and the heat-affected zone is relatively narrow. This results from the simultaneous application of energy and thrust. The resultant torque extrudes the material off its interfaces, throwing out surface inclusions and oxides while working the metals at a plastic state below melting temperature. Flash (the upset or

extruded metal from the weld interface) may be left intact if permitted by design req ' 'ements or it may be removed by machining or shearing.

- The process can be automated for continuous high production (up to 1,000/hour per machine for M42/M46 grenades).

2.3.1.1 <u>Component Design for the Inertia-Welded Process</u>

Material upset and subsequent flash are inherent in the inertia welding process. Flash always occurs at both outside diameter and inside diameter surfaces of the weld interface and must always be considered in the design of parts to be inertia-welded. The basic joint must be a butt weld since the process involves thrusting one part axially against the other.

Early in the program, Dayron contacted and visited Manufacturing Technology, Inc., Mishawaka, Indiana, and worked closely with their engineers to design the optimum M42/M46 grenade body assembly joint for inertia welding. (See Photograph Number 6

and Figure Number 1.)

Kratz-Wilde Machine Company, Covington, Kentucky, was awarded a purchase order to develop a dome for the inertia-welding process. Their approach was to employ the blank, cup and draw method to form the dome. The material used was .119" thick embossed 4140 steel as employed in current M42 grenade body fabrication. The requisite dome configuration must have a relatively broad flange to accept the axial loading required by the inertia-welding process. After considerable work, it was decided that the dome could not be readily produced to the required design with the selected technique because of the consistent severe cracking and peeling up of the fragmentation pattern during the reverse forming operation of the flange. Domes were therefore machined from solid 4140 steel bar stock in order to perform the inertia-welding tests.

An inertia welding machine was tooled at Manufacturing Technology, Inc. and assemblies consisting of embossed tubing and unembossed machined

domes were routinely welded with no difficulty. Tooling and the inertia welding machine setup are shown in Photographs Number 7, 8, 9 and 10.

2.3.1.2 Test Results

Inertia-welded M42 grenade body assemblies were machined to final dimensions, heat-treated, tempered at 725^{o}F and subjected to longitudinal and transverse load tests in accordance with Specification MIL-G-48047. The results were very satisfactory with an average longitudinal strength of 92,000 pounds and an average transverse strength of 9,640 pounds.

2.3.1.3 Conclusions

The inertia welding of a dome to a cylinder produces an acceptable M42/M46 grenade body assembly. The welded joint is superior in strength to any other design tested. There are, however, several shortcomings to this method of fabrication when compared to the furnace-brazed assembly discussed in Section 2.3.2 of this report.

The disadvantages are as follows:

- The dome cannot be fabricated to the required flanged design using embossed material and the standard blank, cup and draw method.

- During the welding operation an exceedingly hard zone is created in the joint area (see Figure Number 2) which must be annealed before final machining operations can be economically performed.

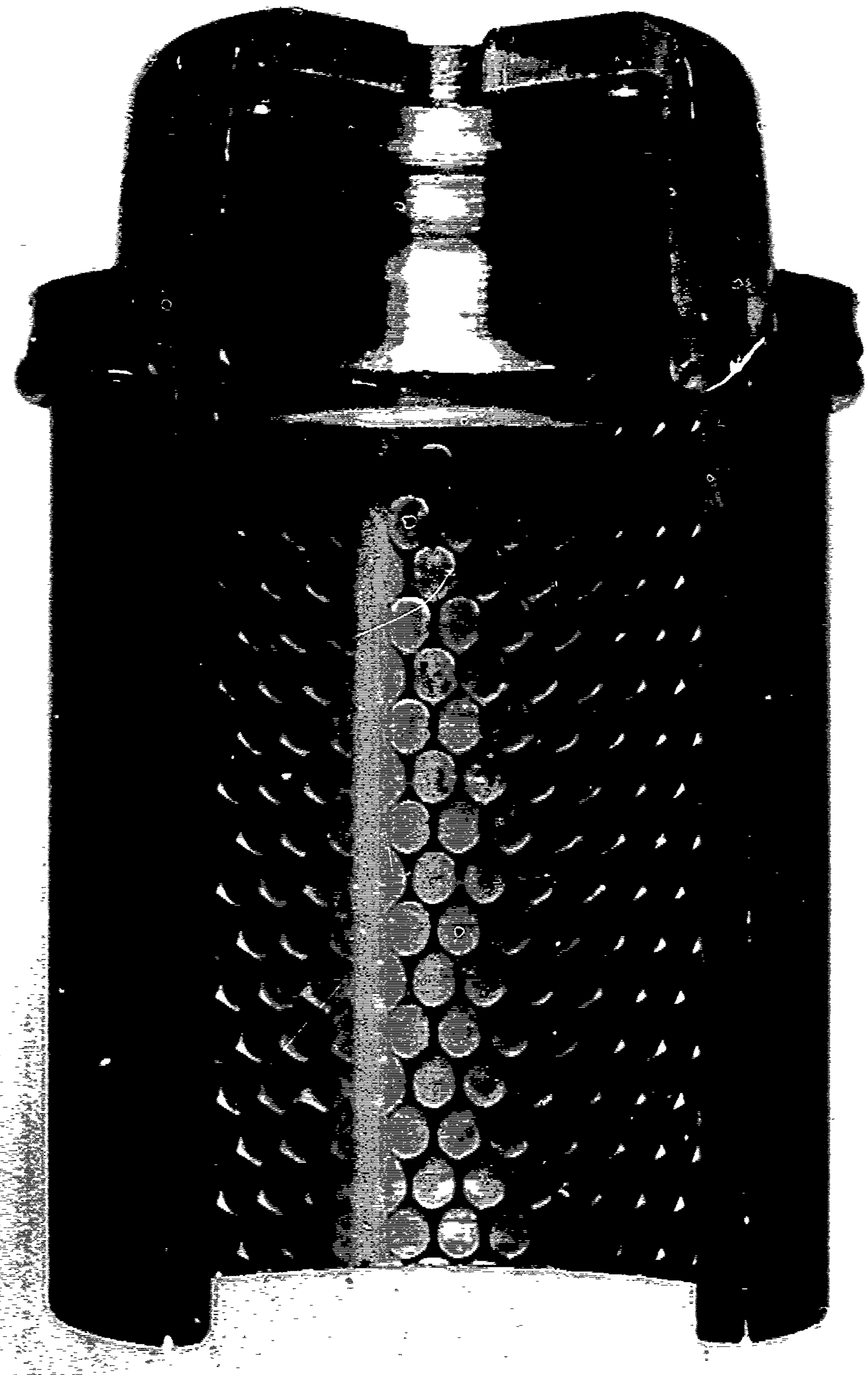
- Considerable flash is produced both in the inside and outside of the assembly during the welding operation. Secondary machining operations must be employed to remove the flash.

- Overall length of the assembly cannot be held to final dimensions during welding and, therefore, the assembly (cylinder length) must be oversize and then machined to final length after welding.

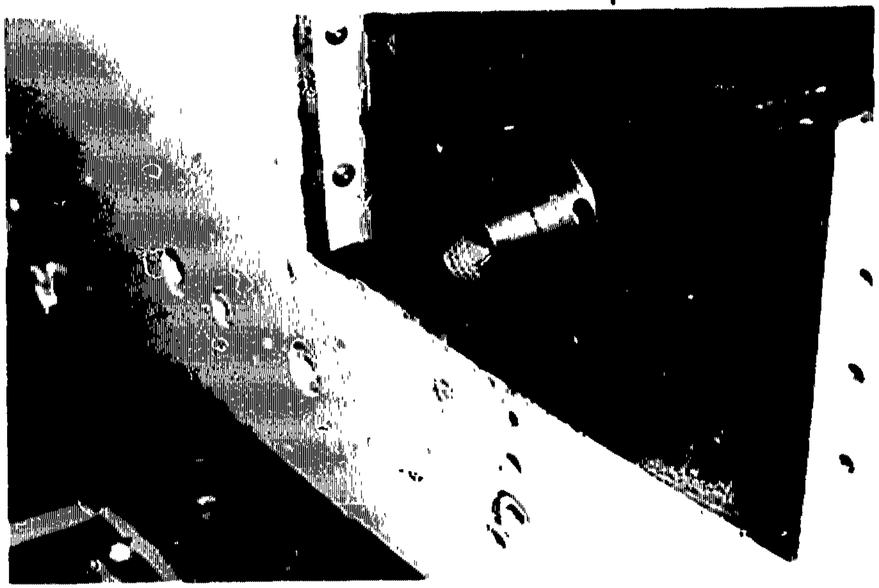
- The inertia welding process and equipment is considerably slower and much more costly than

a furnace brazing system. One automatic welding machine capable of producing 1,000 grenade assemblies per hour would cost $340,800.

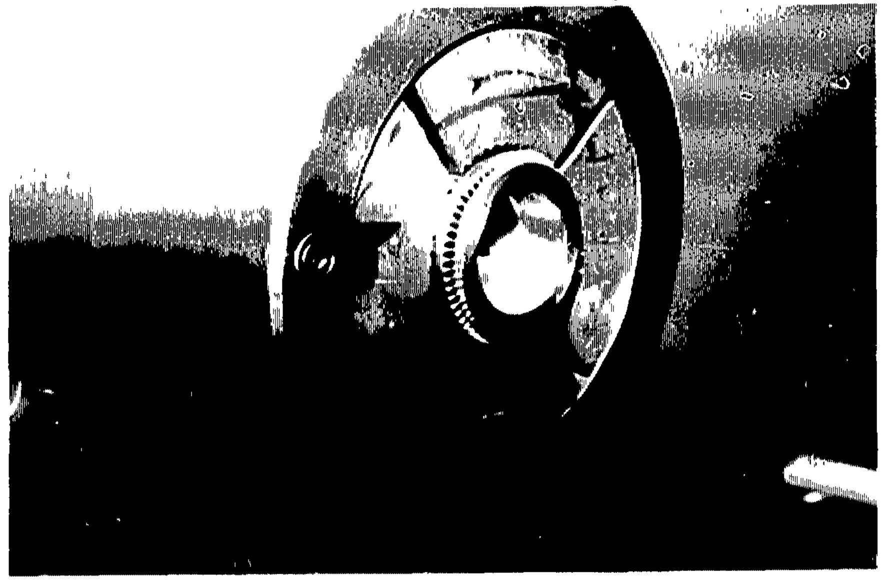
Because of the above disadvantages, and because of the advantages of brazing discussed next, Dayron has selected brazing as the optimum means of attaching the dome to the cylinder.



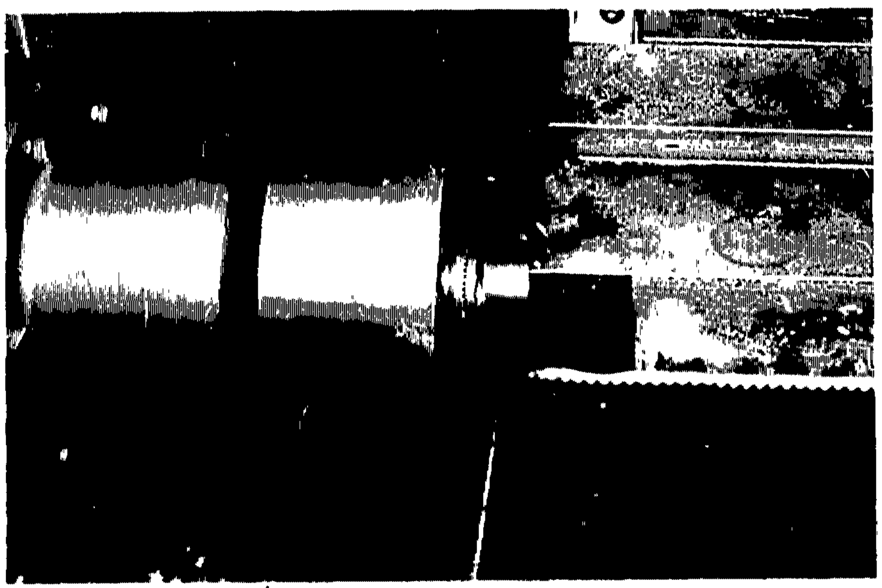
(Photograph 6) INERTIA-WELDED BODY ASSEMBLY
(BEFORE FINAL MACHINING OPERATIONS)



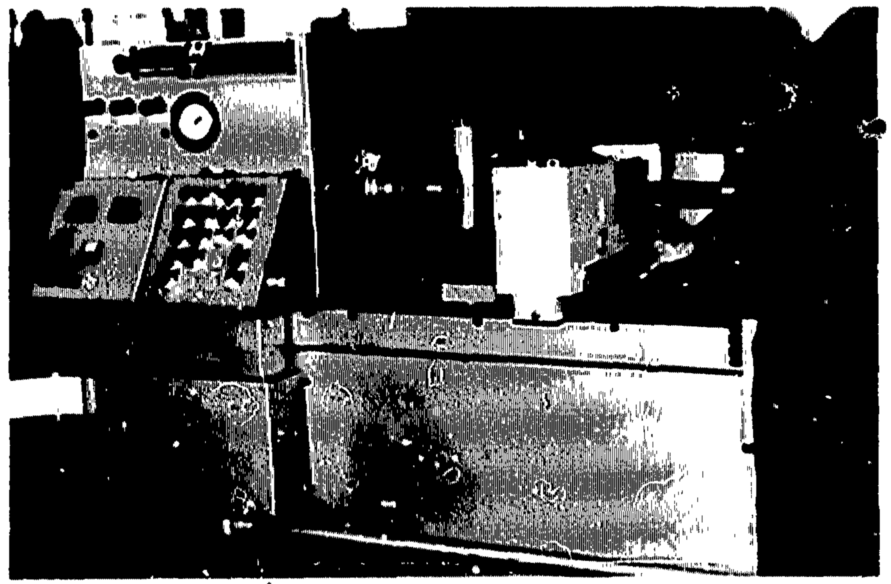
(Photograph 7) CYLINDER BEING HELD IN NONROTATING FIXTURE



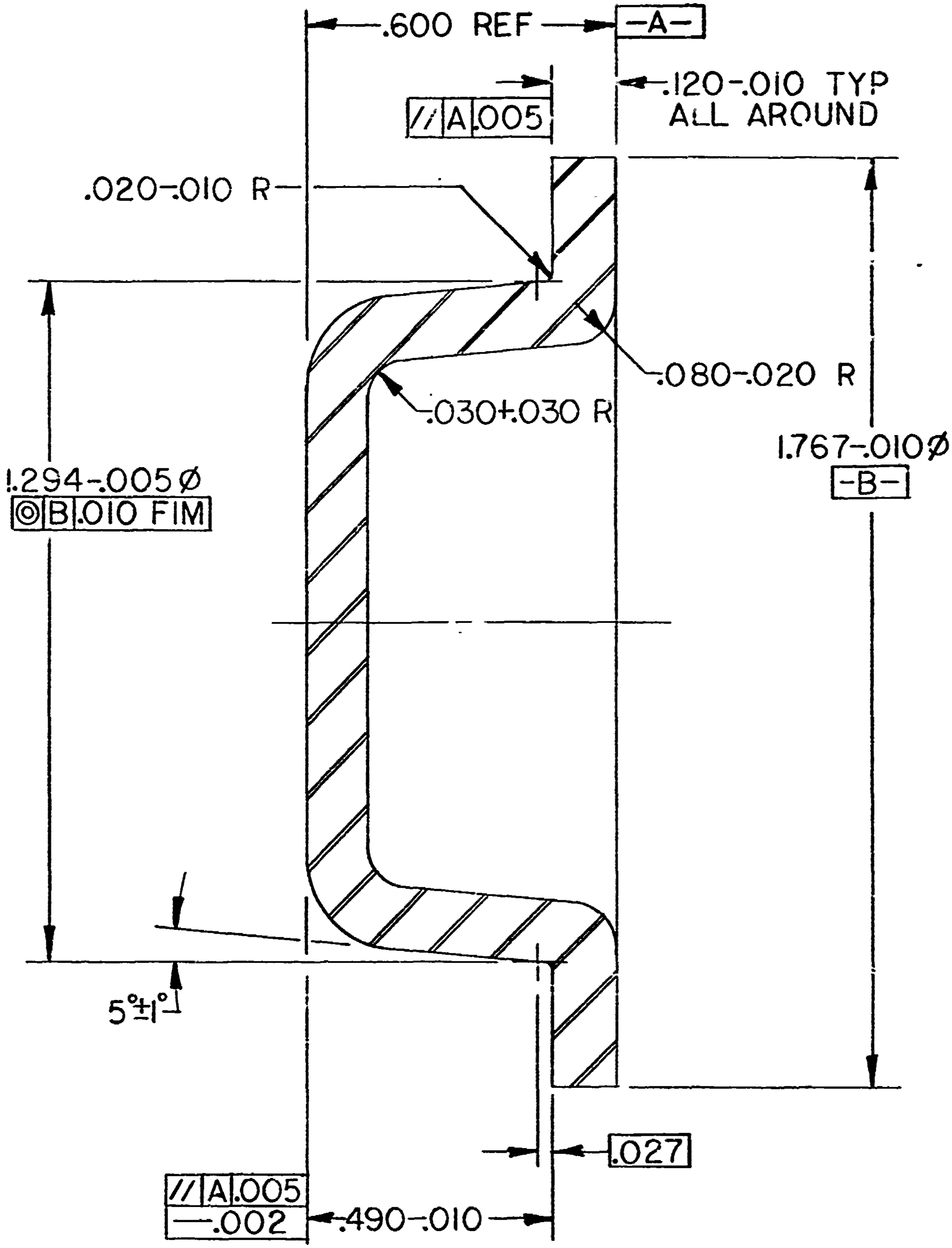
(Photograph 8) DOME BEING HELD IN ROTATING HEAD



(Photograph 9) DOME AND CYLINDER COMING TOGETHER TO BEGIN WELDING CYCLE



(Photograph 10) M42 GRENADE ASSEMBLY BEING INERTIA WELDED



MAT'L:- AISI 4140, SPEC ASTM A507

DOME, GRENADE M46
(For Inertia Welding Process)
Figure 1

INERTIA WELDED GRENADE BODY ASSEMBLY
(Rockwell "A" Hardness Readings After Welding)

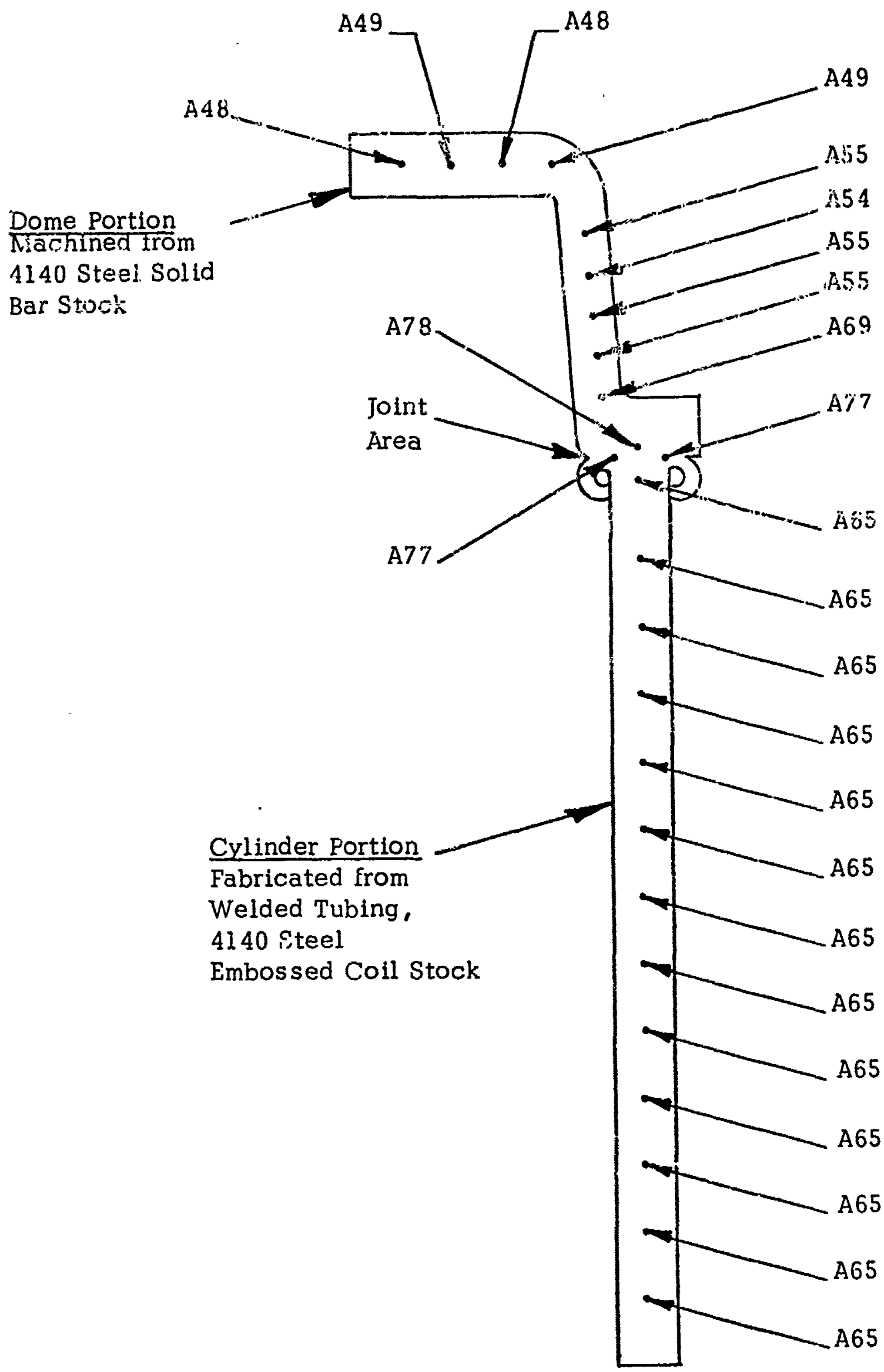
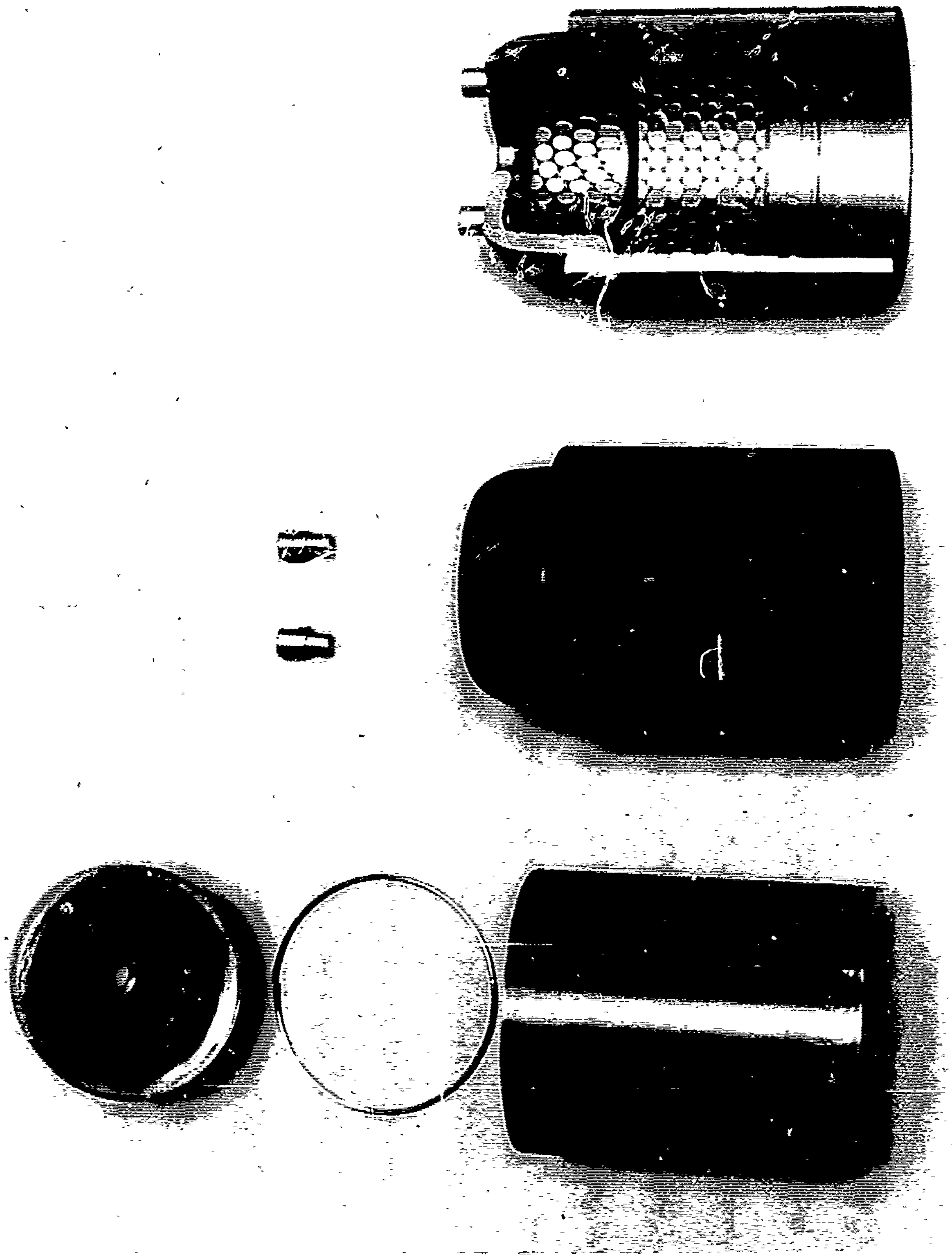


Figure 2



(Photograph 11) M42 BRAZED GRENADE BODY ASSEMBLY AND COMPONENTS

2.3.2 Brazed Assembly

Brazing is a very reliable and economical method of attaching two steel pieces together if the pieces can be designed to provide a proper joining surface. The attachment of two cylinders of different diameters is an ideal configuration for brazing. The M42/M46 dome/cylinder design approaches the optimum for the brazing technique.

Brazing provides the following advantages:

- Produces a leaktight joint. In brazing, capillary action draws the molten filler metal into every crevice of the closely fitted joint area, filling it completely. There are no voids or gaps.

- Produces a ductile joint. Brazing joins metals at relatively low heats (when compared to welding), causing little or no brittleness or stress in the joint area. The ductility of the joint is further increased by the broad width of the typical lap joint to be used in the M42/M46 grenade body. The combination of these two factors imparts resistance to joint cracking or failure under severe conditions of shock, vibration or sudden temperature change.

- Produces corrosion-resistant joint. Even a highly corrosive atmosphere cannot corrode what it cannot reach. A brazed joint is hard to reach since practically all the filler metal is contained inside the joint, with only a very fine line or fillet exposed at the surface.

- Produces joints requiring no finishing. The small surface fillet or thin edge of a brazed joint requires no special cleanup. A welded joint, however, requires certain finishing operations which can include removal of excess weld metal, annealing, machining to size and stress-relieving to restore the metallurgical properties and final dimensions of the welded assembly. On a production basis, these cost differences become significant.

- High-production adaptability. A brazing process can be economically established to produce millions of assemblies per month on a fully or partially automated basis. When compared to other assembly methods, a proven brazing process requires minimal controls and monitoring to consistently produce reliable assemblies.

The following types of brazing techniques were investigated for use in fabricating the two-piece M42/M46 grenade body assembly:

- Multiple burners. This is the first step up from the manual torch. A series of open-flame burners are screwed into a pipe which is attached to a gas-air compressor. A conveyor or turntable carries the assemblies past these burners. The size and positioning of the burners are coordinated with conveyor speed to bring just enough heat to the parts. This is a simple, inexpensive and effective way to automate heating of small assemblies.

- Electric induction. This is a selective heating method in which the joint assembly is placed in a high-frequency electric field. Heating is fast and confined to a limited area on the part. The heating cycle can be automatically timed to produce joints of consistent quality.

- Furnace heating. This is a high-production heating method for similar-mass, small or medium-size

assemblies such as the M42/M46 grenade bodies. The parts to be brazed are initially assembled, brazing alloy preplaced at the joint and the assemblies then fed into a furnace which heats them to a predetermined temperature. The parts emerge fully brazed.

There are several types of brazing furnaces -- batch or continuous, electrically heated or gas-fired. Furnaces may use controlling atmospheres to prevent oxidation, in which case fluxing may not be necessary. For production of extremely critical brazed assemblies, vacuum-furnace brazing is frequently used. This method produces brazed joints of exceptional purity by eliminating the presence of all gases. After considerable study and consultation with the following brazing and furnace equipment manufacturing companies, Dayron elected to evaluate both the controlled atmosphere and vacuum furnaces for use on the M42/M46 grenade program.

- Handy & Harman, New York, New York
- Lucas-Milhaupt, Inc., Cudahy, Wisconsin
- Sunbeam Corporation, Meadville, Pennsylvania

- Ipsenlab, Rockford, Illinois
- Lindberg (Sola Basic Industries) Chicago, Illinois

A discussion of these two selected processes appears in Section 2.3.2.3 of this report.

2.3.2.1 Component Design for the Brazing Process

In brazing, the molten filler metal is drawn by capillary action between contiguous, closely fitted, substantially symmetrical surfaces. The distance the filler metal will flow in a joint depends both upon the clearance between the mating surfaces and upon the filler metal used. Molten copper will flow freely and for greater distances than other filler metals in joints with size-to-size fit (zero clearance) or an interference fit (negative clearances). The distance of copper flow increases as joint interference increases, up to the point where the seizing and galling of mating surfaces interferes with capillarity. Conversely, as joint clearance, or gap, is increased, a clearance is reached at which filler metal flow stops completely. Uniform fit throughout the joint is important because nonuniform fit will result in nonuniform strength.

For most applications, the recommended fit for copper brazing of low-carbon steel is 0.000" to 0.003" interference. High-carbon steels require a slightly looser diametral fit, usually 0.001" clearance to 0.002" interference. It is, however, important to note that joints with as much as 0.003" diametral clearance will exhibit a strength exceeding the average shear strength of copper.

In general, lap joints are preferred for brazing. The strength of these joints results from braze material penetration between close, conforming surfaces, rather than on external fillets. For optimum strength, the length of the joint should be between two to three times the thickness of the thinnest section.

Considering the above information, which was obtained from the American Society for Metals on furnace brazing of steel and from consultation with several other authorities on the subject, Dayron elected to employ the following joint for the two-piece M42/M46 grenade body assembly: 0.003" interference to 0.001" clearance

fit of the dome to the cylinder and a lap joint of .238" length.

2.3.2.2 Braze Material

Copper is the preferred filler metal for furnace brazing of carbon steel assemblies without flux in reducing protective atmospheres or in a vacuum. Significant amounts of the two trace elements, arsenic and phosphorus, cause brittle compounds in the brazed joint. The copper to be utilized in the brazing process, therefore, must be essentially free of arsenic and phosphorus.

A principal advantage of the copper filler metal used in the furnace brazing of steel is the high strength it imparts to the brazed joint. The shear strength of copper joints in low-carbon steel generally ranges from 22,000 to 31,000 psi, while tensile strength ranges from 25,000 to almost 50,000 psi.

Copper filler metals have the advantage of low cost, especially when compared to most other filler metals which contain silver. The cost of silver alloy filler metal in wire form varies from 5 to 20 times the

cost of an equal volume of copper filler metal depending upon the silver content in the alloy.

Further, a flux is required when using silver alloy filler metal. The basic cost of the flux plus the costs of application and cleansing make silver brazing noncompetitive with copper brazing. Copper filler metals, when used in conjunction with a suitable protective atmosphere in the brazing of steel, are self-fluxing because the furnace atmosphere reduces surface oxides and thereby promotes the flow of the copper material.

Dayron has selected the following copper material for use on the M42/M46 grenade body assembly: copper alloy wire, Spec ASTM B260-62T in a preform configuration using .031" diameter wire formed into a 1.287" inside diameter circle.

2.3.2.3 Braze/Heat-Treat Process

To fully realize the maximum potential savings, the two-piece M42/M46 brazed grenade assembly must be brazed and heat-treated in one continuous or semi-continuous operation. Two processes that meet these requirements are as follows:

- Continuous (Inert Gas)
- Batch (Vacuum)

2.3.2.3.1 Continuous Braze/Heat-Treat (Inert Gas)

Dayron has selected the continuous-type braze/heat-treat process as the most cost-effective practicable means of brazing. This process, proposed by the Lindberg Company (Sola Basic Industries), Chicago, Illinois, is described in the following paragraphs. This technique will braze, harden and temper the Dayron two-piece M42/M46 grenade body assembly in one continuous automatic operation. The total price for the complete installation of the system is approximately $240,000.

The system will be capable of handling 896 pounds (2,700 grenades) per hour. Basically, the brazing furnace will be adjacent to the tempering furnace in a U-shaped process flow. Loads will be charged and discharged at opposite

sides of the "U" at the same end of the system. Estimated floor space for the complete brazing installation is approximately 60 feet long by 20 feet wide. The furnace shell will be a gas-tight welded construction. The inert protective gas will flow counter to the direction of the load conveyors. The overall length of the furnace will be approximately 50 feet including a three (3)-foot conveyorized loading station in which the grenades will be placed on 2-1/2" centers. A copper preform brazing ring will be initially placed on the grenade by an automatic assembly machine prior to grenade emplacement on the furnace loading station.

The furnace will have a total input of 250 KW in six (6) zones of control with six (6) separate instruments for controlling temperature and will include a high-limit protection device. The atmosphere required for this furnace will be approximately 800 cubic feet per hour of endothermic gas which will be provided by a 1,000 CFH atmosphere generator.

The brazing and hardening portion of the system will have a conveyor belt width of approximately 36". The belt will ride on a silicon carbide hearth with heating elements of silicon carbide above and below the hearth to perform the brazing operation at 2050°F. The heating chamber will be 24 feet long including a two (2)-foot, high-heat section for the brazing operation, followed by an eight (8)-foot insulated section to reduce the temperature, followed by an eight (8)-foot hardening section which will be maintained at 1550°F. After passing through the 1550°F zone, the grenades will be transported into an oil quench tank filled with recirculated oil for uniform quenching. The parts will then be removed from this tank on a 24-inch wide conveyor and processed through a washer which will remove the quenching oil. The parts then will be properly emplaced on the tempering furnace conveyor belt.

The tempering furnace will have a belt length of 24 feet, a belt speed of approximately

33 feet per hour, and a belt loading of 11 pounds per square foot. This furnace will have an overall length of approximately 55 feet consisting of a three (3)-foot load table; one (1)-foot vestibule; twenty-four (24)-foot heated section; three (3)-foot insulated cool section; and a twenty-four (24)-foot water cool section which will permit removing the parts at room temperature. The furnace will be rated at an input of 70 KW. It will have three separate temperature zones. Each zone will contain its own temperature controls, including individual high-limit protection devices.

2.3.2.3.2 Batch Braze/Heat-Treat (Vacuum)

Brazing and heat-treating in a vacuum environment produces the most consistent and reliable product. All grenade body assemblies used in this program were furnace-brazed in an Ipsen vacuum furnace. The initial production facility to vacuum braze and heat-treat 1,400,000 assemblies per month is approximately

twice the cost of the more conventional continuous (inert gas)-type process. Our initial evaluation is that the inert gas system will produce acceptable M42 grenade bodies and that the vacuum system is not required. However, before a final decision is made on establishing a totally new M42/M46 two-piece brazed grenade body assembly facility, further in-depth comparison studies of long-range cost, product quality and reliability of the two methods (inert gas versus vacuum) should be made.

The new Ipsen three-zone vacuum furnace operates in the following sequence:

- Zone 1. The grenade body assemblies with preformed brazing rings attached are placed into the furnace. The air is evacuated and parts are then automatically transferred from the Zone 1 compartment into Zone 2.

- Zone 2. Zone 2 is programmed to do the brazing operation at a temperature of 2050°F. After brazing, the temperature is lowered to the heat-treat temperature of 1550°F and the batch is then automatically transferred to Zone 3.

- Zone 3. The batch is quenched in oil and the vacuum released. The Zone 3 portion of the furnace is then opened and parts removed.

The three zones are actually separate chambers within one larger chamber with vacuum-tight doors on each end and two vacuum-tight movable bulkheads in the middle. The middle bulkheads are moved vertically to allow the parts to be automatically transported from Zone 1 into Zone 2 and from Zone 2 into Zone 3. It is a very effective and efficient piece of equipment. Once the assemblies enter the furnace, they remain continuously in a vacuum environment until removed from Zone 3.

Note: After the initial load of parts leave Zone 1, the vacuum is released in Zone 1 so that the chamber can be reloaded. Approximately 3,000 grenades (one batch) can be processed each hour.

The hardened parts would be tempered in a separate conventional atmosphere-controlled unit.

Total cost for the complete system including the tempering unit is approximately $445,000.

2.3.2.4 Longitudinal, Transverse Load and Push-Out Tests

Approximately 170 load tests were performed on the brazed M42 grenade bodies. Early in the program it was decided that significant effort would be directed toward developing an M42 grenade body that would be physically strong enough to pass all the requirements of the M46 grenade body. If successful, the M46 (no embossing) grenade could then be eliminated from the M483 round, thereby increasing its effectiveness and simplifying round producibility.

Initial tests indicated that the two-piece brazed M42 grenade body would meet the longitudinal and transverse load requirements of the M46. With the initially selected tempering temperature of 725°F, the longitudinal load results averaged 90,900 pounds and the transverse results averaged 9,250 pounds. These averages exceeded the specified M46 grenade body requirements. Based upon those results, approximately 300 M42 grenades were fabricated, heat-treated and tempered at 725°F. A sample of 50 units was selected and tested in accordance with the M46 grenade body specification, MIL-G-48047, paragraphs 4.3.3.3 and 4.3.3.4. The average longitudinal strength of the sample was 86,270 pounds and the average transverse strength was 8,934 pounds. Though the averages were acceptable, the $\bar{x}$ minus 3 sigma (average minus 3 standard deviations) value equated to 80,538 pounds for the longitudinal strength which did not meet the 85,000 pound requirement. The transverse strength value of $\bar{x}$ minus 3 sigma was 7,531 pounds, sufficient to satisfy the specification requirement.

Further tests were then run to establish the optimum tempering temperature. It became apparent that as the hardness of the material increased, the longitudinal strength increased and the transverse strength decreased. All the test results obtained from bodies subjected to various tempering temperatures were compiled and used to construct a graph to show the relationships of tempering temperatures, material hardnesses and grenade body strengths. (See Figure Number 3.)

This graph indicates that the brazed M42 grenade body assembly can readily pass either the longitudinal or the transverse requirements for an M46 grenade, but will have difficulty passing both requirements at the same time using the $\bar{x}$ minus 3 standard deviation criteria.

<u>IMPORTANT NOTE</u>: The inside diameter dimension of the cylinders we tested, as mentioned earlier in Section 2.1.1, is oversize approximately .020" which reduces the transverse strength. Additionally, the oversize inside diameter tubing did not allow the embossed pattern to be totally removed from the braze

joint area; this also may have reduced the ability of the joint/assembly to withstand transverse loads.

From the test results obtained, it was decided that the optimum tempering temperature would be $675^{O}F$. Two hundred (200) assemblies which were previously tempered at $725^{O}F$ were rehardened and then tempered at $675^{O}F$. These units were shipped to ARRADCOM for final testing and evaluation.

Further testing of the two-piece M42 grenade body should be conducted using cylinders fabricated to the correct dimensions to develop the correct techniques which would meet M46 grenade requirements. It is important to note that the basic M42 grenade body strength requirements of 65,000 pounds (longitudinal) and 6,300 pounds (transverse) were most readily achieved with the two-piece embossed brazed assembly.

No M46 grenade body brazed assemblies were fabricated or tested because of the recognizable success we achieved with the M42 grenade configuration and our objective to eliminate entirely the need for the M46

M42 BRAZED ASSEMBLY GRENADE BODY

(Longitudinal/Transverse Strengths vs. Tempering Temperatures)

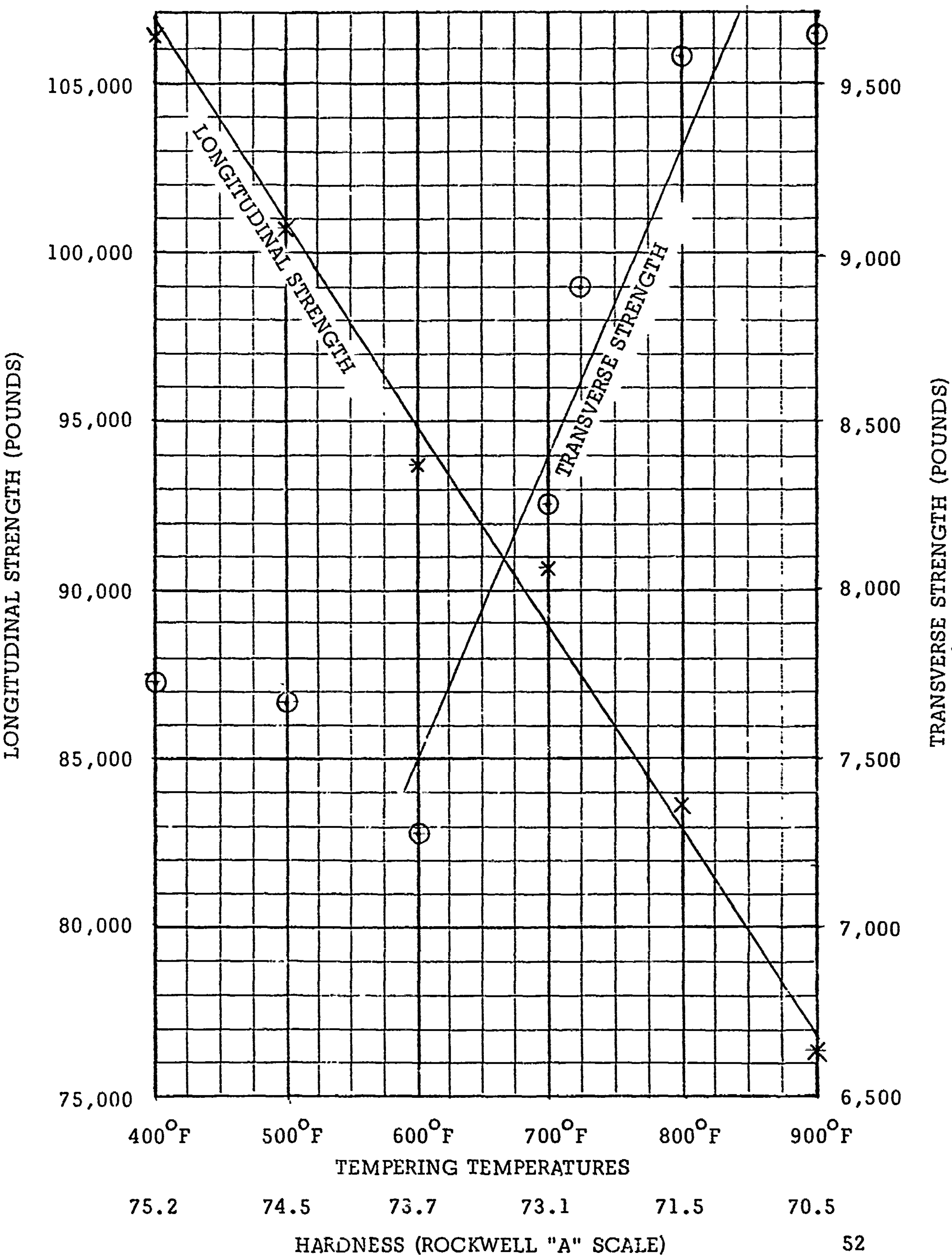


Figure 3

grenade. It is evident from the M42 grenade body test results that a solid (nonembossed material) two-piece design would quite easily satisfy all M46 grenade strength requirements.

A push-out test was conducted as shown on Final Drawing 9327240 to test the strength of the brazed joint to ascertain that it would safely endure projectile firing setback loads. Failure occurred at 28,500 pounds.

According to the information obtained from ARRADCOM, the maximum setback forces to which the grenade will be exposed are 14,600 g's. The total weight of the M223 fuze, tape stiffener assembly, studs, dome, explosives and shaped charge liner is 113.2 grams (.249 pounds). This weight acted on by the maximum g-load results in 3,636 pounds maximum load to which the brazed joint could be subjected during operation. Actual joint failure occurs at 28,500 pounds; more than a seven (7) times safety factor. Dayron selected a safety factor of two (2) or 7,500 pounds to be adequate for this requirement. If desired, this requirement could be checked (nondestructively) 100 percent during production in the automatic stud assembly machine.

2.4 Quality Assurance

Throughout the development program to design and produce an economical and reliable M42/M46 two-piece grenade body assembly, Dayron constantly compared piece parts to applicable drawing requirements. The following five areas were considered to be of prime importance:

(1) Brazing and heat-treatment of the body assembly

(2) Integrity of the brazed joint

(3) Longitudinal and transverse strength of the body assembly as tested in accordance with Specification MIL-G-48047

(4) Tensile force to remove studs from dome

(5) Dimensional control of component parts

These five areas are discussed below:

2.4.1 Brazing and Heat-Treatment of the Body Assembly

All body assemblies were brazed in an electrically heated Ipsen vacuum furnace and heat-treated in an atmospherically controlled gas-heated furnace. The brazing temperature was 2050°F and the hardening temperature was 1550°F. Tempering temperatures were varied from 400° to 900°F

in order to provide data for determining the optimum tempering temperature. (See Figure Number 3.)

One problem experienced during the brazing operation was the failure of the braze material to flow consistently into the joint area. Prior to sample fabrication, we consulted with industry metallurgists to determine the proper braze joint configuration for the M42/M46 cylinder/dome grenade body. These consultants uniformly agreed with the basic joint design, but there was not total concurrence in the joint preparation design. One group held the opinion that no chamfer or groove was necessary to direct the flow of the molten copper into the joint, but the other consultants concluded that a chamfer would be necessary.

The initial sample cylinders were therefore fabricated with a chamfer in which the copper brazing ring would rest. The chamfered units were fully satisfactory. The next sample cylinders were produced with no chamfer and 20% of the joints failed to fill with copper during brazing.

Subsequently, all the remaining body assemblies were fabricated with cylinders containing a chamfer to direct the

flow of the copper directly into the joint area. Approximately 400 assemblies were produced in this configuration and each joint filled and bonded properly. No other brazing or assembly problems were experienced during the duration of the contract.

2.4.2 Integrity of the Brazed Joint

A random sample of approximately 20 body assemblies was selected and subjected to a push-out test as shown on Drawing Number 9327240. All joints exhibited 100% filling with no voids or defective areas evident after being sheared from the cylinder. The force required for removing the domes was approximately 28,500 pounds.

Note: As discussed earlier, the maximum load to which the brazed joint could realistically be subjected during projectile firing operations is 3,636 pounds. A safety factor exceeding seven (7) is therefore exhibited by the selected brazed joint.

2.4.3 Longitudinal and Transverse Strength of the Body Assembly as Tested in Accordance With MIL-G-48047

Two-piece, brazed M42 bodies were tested for longitudinal and transverse strength. When hardened and tempered at 725°F, the following results were obtained: average

longitudinal strength, 86,270 lbs.; average transverse strength, 8,934 lbs. These average strength values substantially exceed both the M42 grenade requirements and the more severe M46 grenade requirements. The normal variation-in-strength values, however, resulted in the three sigma limit of the longitudinal strength falling below the M46 grenade requirement of 85,000 lbs.

Subsequent testing of bodies tempered at various temperatures revealed the following trade-off: as tempering temperature increases, longitudinal strength decreases while transverse strength increases. As a result of these data, we selected a compromise tempering temperature of 675°F for the deliverable units to be tested by ARRADCOM. It should be noted that these results were accomplished with grenade bodies which were slightly undersize in wall thickness; a factor which certainly decreased the measured transverse strength. It is expected that grenade bodies held to specified dimensions and properly heat-treated will meet the strength requirements for both M42 and M46 grenades.

2.4.4 Tensile Force to Remove Studs from Dome

Each stud must withstand a 500-pound minimum tensile force between stud head and body as set forth on Drawing

Number 9327240. Dayron obtained studs that were being used in current production grenades and noticed that the shank lengths were developed for riveting into grenade material .112" thick. The dome of the Dayron grenade is .006" thicker at .118".

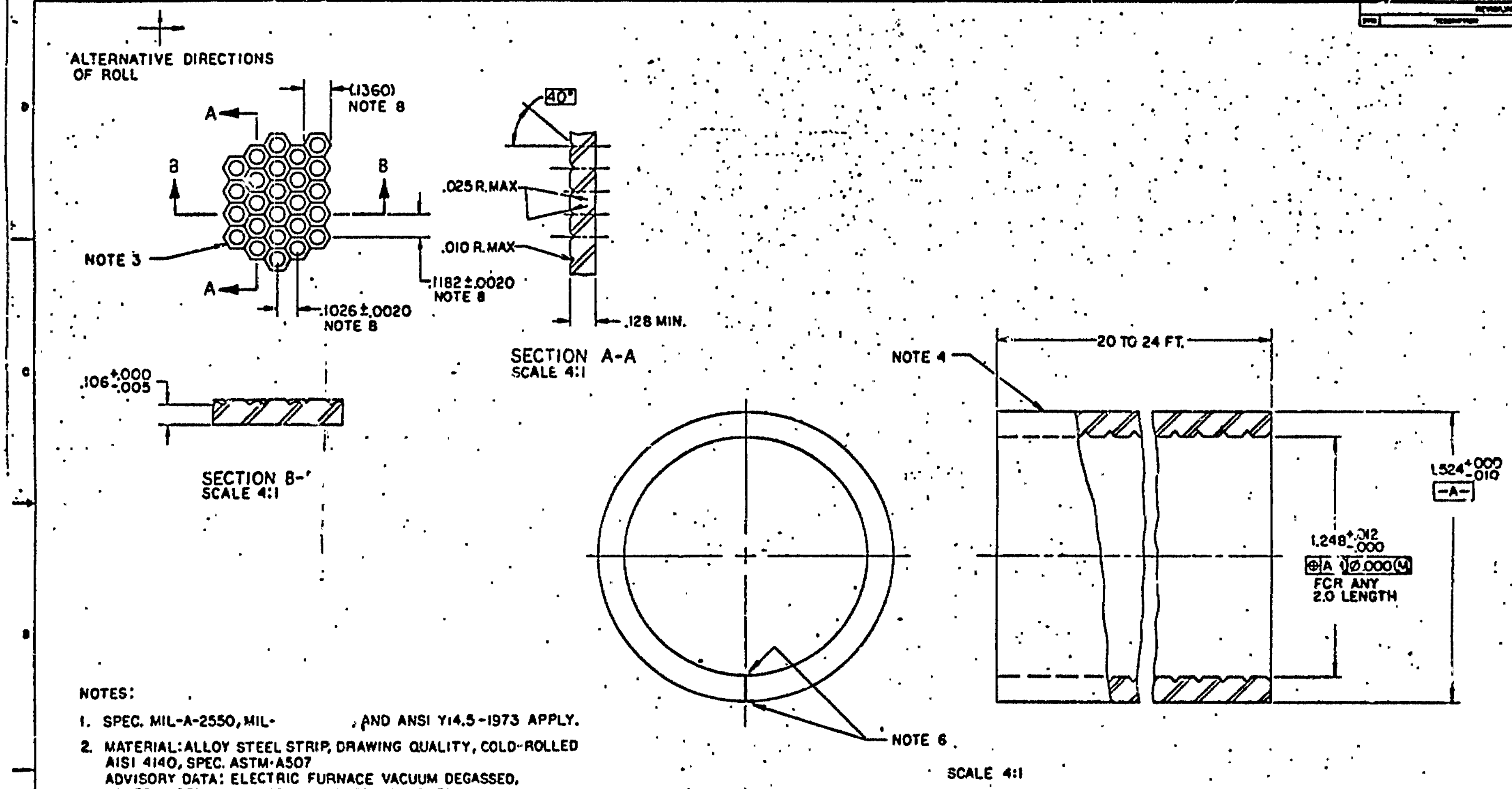
Tensile tests using the current length studs ranged between 550 to 700 pounds which is not considered an acceptable margin of safety for reliability in high-volume production. A stud shank length of .138" would assure an average tensile strength of approximately 900 pounds. Grenade assemblies as delivered to the customer for test contain the current .132" length stud shanks and, therefore, may be marginal in tensile strength.

2.4.5 <u>Dimensional Control of Component Parts</u>

For the performance of this contract, Dayron did not design or purchase any special gaging for measuring component dimensions or features. Only standard gaging and equipment was employed. For high-production assembly quantities, a large array of specialized gaging would be warranted. The Government's basic gaging package, specifications and inspection procedures approved for use by current M42/M46

grenade body producers are acceptable with slight modifications for use on the proposed two-piece grenade body assemblies.

Components and grenades were sampled from the lot submitted to ARRADCOM for testing and inspected to the requirements of the following drawings: 9327237, 9327238, 9327239, 7327240 which appear on the following pages. The results of these dimensional inspections and destructive load tests indicate that the two-piece brazed grenade body assembly is safe to be loaded and used in ballistic and functional testing.



NOTES:

1. SPEC. MIL-A-2550, MIL- , AND ANSI Y14.5-1973 APPLY.
2. MATERIAL: ALLOY STEEL STRIP, DRAWING QUALITY, COLD-ROLLED AISI 4140, SPEC. ASTM-A507
   ADVISORY DATA: ELECTRIC FURNACE VACUUM DEGASSED.
   SPHERODIZED ANNEALED WITH 90% MIN. SPHEROIDS
   ROCKWELL B85 MAX, NUMBER 2 FINISH OILED, THICKNESS .130 ±.002
3. COINED CONFIGURATION IN FLAT STRIP BEFORE FORMING AND WELDING INTO TUBING
4. MATERIAL TO BE FORMED INTO TUBING, WELDED, ANNEALED AND STRAIGHTED BY BABCOCK & WILCOX TUBULAR PRODUCTS DIVISION, ALLIANCE, OHIO OR OTHER APPROVED GOVERNMENT SOURCE
5. TUBING HARDNESS ROCKWELL A65 MAX.
6. WELDING FLASH TO BE REMOVED DURING TUBING FABRICATION PROCESS. AFTER FLASH REMOVAL WELD MAY BE .005 ABOVE OR BELOW MATERIAL SURFACE
7. TUBING TO BE EDDY CURRENT INSPECTED PER ASTM 513-76
8. TOLERANCES TO BE NON-ACCUMULATIVE.

PART NO. 9327237

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND DOVER, NEW JERSEY 07801

TUBING, EMBOSSED

D	19200	T	9327237
SCALE 4:1			

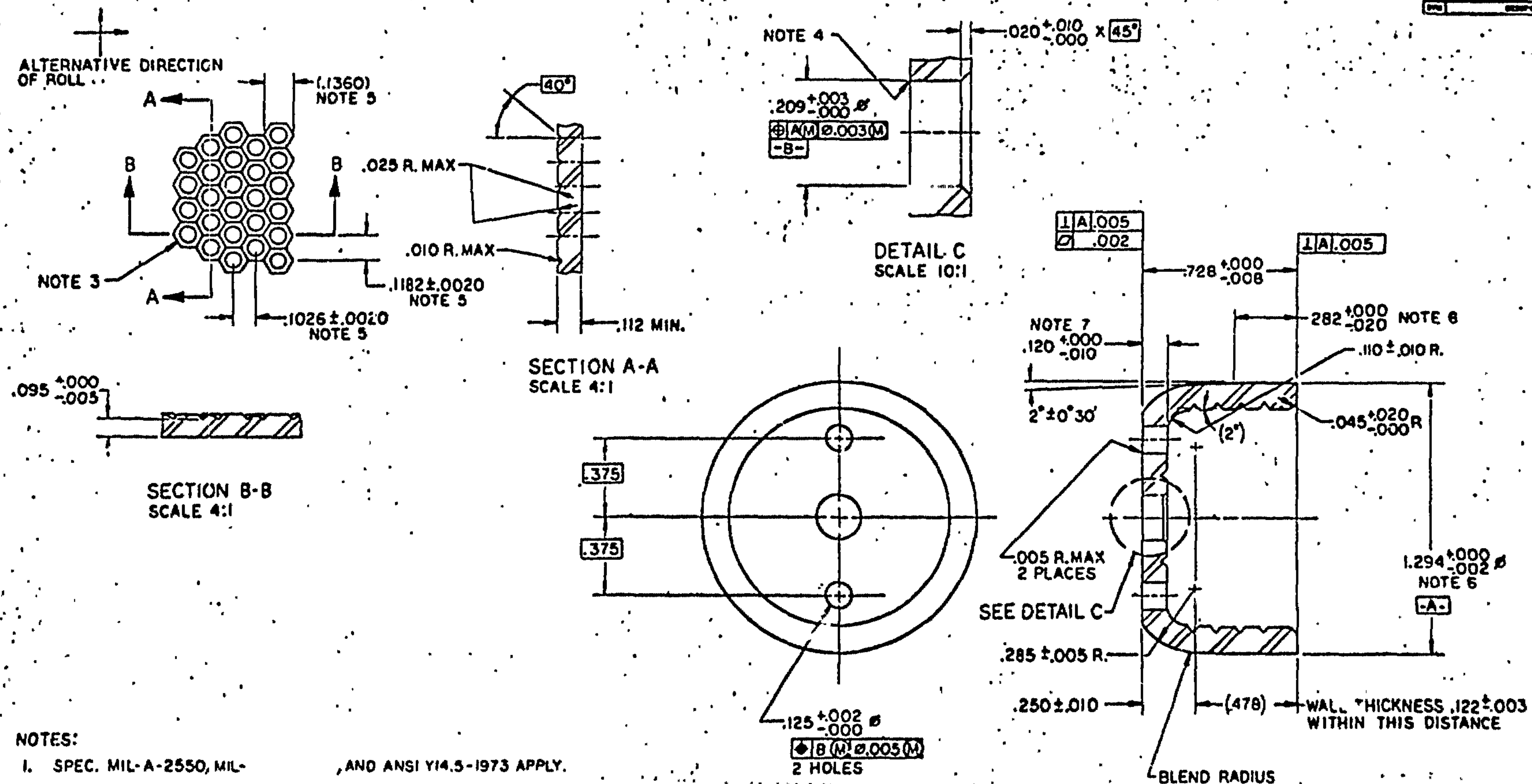
9327239

APPLICATION

DO NOT SCALE DRAWING

DRAFTSMAN PA

CHECKER WH



NOTES:

1. SPEC. MIL-A-2550, MIL- , AND ANSI Y14.5-1973 APPLY.
2. MATERIAL: ALLOY STEEL STRIP, DRAWING QUALITY, COLD-ROLLED AISI 4140, SPEC ASTM A507
   ADVISORY DATA: ELECTRIC FURNACE VACUUM DEGASSED, SPHEROIDIZED ANNEALED WITH 90% MIN SPHEROIDS, ROCKWELL B85 MAX, NUMBER 2 FINISH OILED, THICKNESS .119±.002.
3. COINED CONFIGURATION IN FLAT STRIP BEFORE FORMING
4. BREAK INCREASING HOLE DIAMETER AT OUTER SURFACE, DUE TO PIERCING OPERATION IS ACCEPTABLE. SPECIFIED DIAMETER OF HOLE SHALL BE MAINTAINED BELOW A DEPTH OF .065 MAX FROM OUTSIDE SURFACE
5. TOLERANCES TO BE NON-ACCUMULATIVE.
6. 1.294 DIA. MUST BE .262 MIN. LENGTH.
7. MATERIAL THICKNESS OVER EMBOSSMENTS AFTER FORMING.

PART NO. 9327238

DOME, EMBOSSED

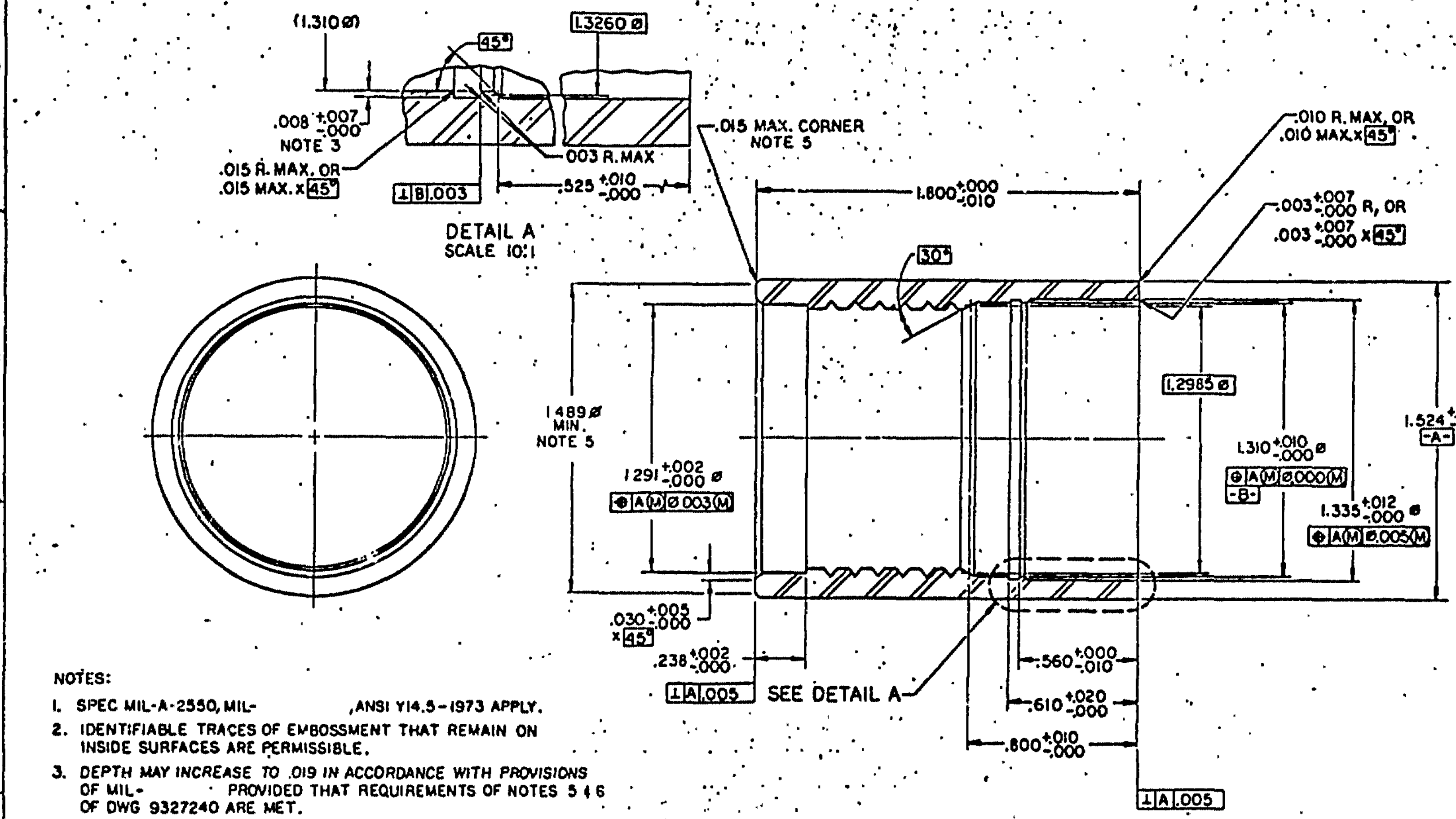
09237240	D	19200	T	9327238

SCALE 4:1

DO NOT SCALE DRAWING

APPLICATION

PA WH

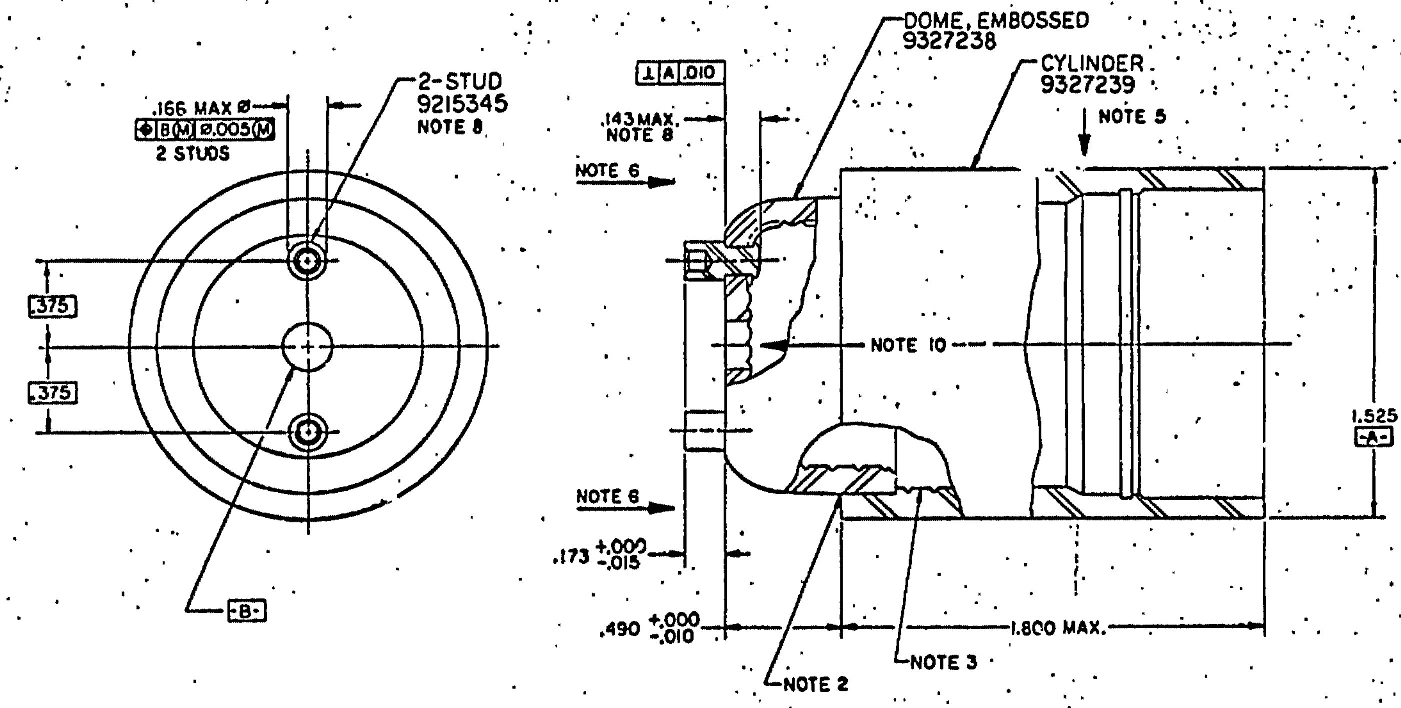


NOTES:

1. SPEC MIL-A-2550, MIL- , ANSI Y14.5-1973 APPLY.
2. IDENTIFIABLE TRACES OF EMBOSSMENT THAT REMAIN ON INSIDE SURFACES ARE PERMISSIBLE.
3. *DEPTH MAY INCREASE TO .019 IN ACCORDANCE WITH PROVISIONS* OF MIL- PROVIDED THAT REQUIREMENTS OF NOTES 5 & 6 OF DWG 9327240 ARE MET.
4. MATERIAL:—MAKE FROM TUBING, EMBOSSED 9327237.
5. .015 MAX. CORNER BREAK TO 1.489 MIN. DIA. PERMISSIBLE AS SHOWN.

PART NO. 9327239

D9327240	APPLICATION
DRAFTSMAN PA	CHECKER WH
CYLINDER	
D	19200
T	9327239
SCALE 4:1	



NOTES:

1. SPEC MIL-A-2550, MIL- ,AND ANSI Y14.5-1973 APPLY.
2. FURNACE BRAZE DOME TO CYLINDER USING COPPER ALLOY WIRE, SPEC. ASTM B260-62T 1.287 I.D. X .031 DIA. PREFORM ADVISORY.
3. BRAZE MATERIAL PRESENT IN EMBOSSED AREA OF CYLINDER IS PERMISSIBLE.
4. HEAT TREAT TO ROCKWELL A76 MAX. ADVISORY PER SPEC MIL-H-6875. FACT THAT BODY HAS BEEN HEAT TREATED SHALL BE VERIFIED.
5. PART MUST EXHIBIT A TRANSVERSE STRENGTH OF 7,500 POUNDS MINIMUM IN ACCORDANCE WITH MIL- WHEN A COMPRESSIVE FORCE IS APPLIED AS SHOWN.
6. PART MUST EXHIBIT A LONGITUDINAL STRENGTH OF 85,000 POUNDS MINIMUM IN ACCORDANCE WITH MIL- WHEN A COMPRESSIVE FORCE IS APPLIED TO SHOULDERS AS SHOWN.
7. PROTECTIVE FINISH: TYPE 1 SPEC TT-C-490, PHOSPHATE COATING, WEIGHT SHALL BE A MINIMUM OF 600 MG/SQ.FT. TO BE APPLIED AFTER BRAZING AND HEAT TREAT OPERATIONS.
8. RIVET SHANK END OF EACH STUD AS SHOWN AFTER PROTECTIVE FINISH HAS BEEN APPLIED
9. EACH STUD MUST WITHSTAND A 500 POUND MINIMUM TENSILE FORCE BETWEEN STUD HEAD AND BODY.
10. DOME MUST WITHSTAND A PUSHOUT FORCE OF 7,500 POUNDS IN DIRECTION SHOWN.

PART NO. 9327240

DO NOT SCALE DRAWING

APPLICATION

PA WH

BODY, ASSEMBLY

D 19200 T 9327240

3. PROPOSED M42/M46 GRENADE BODY FABRICATION PROCESS

Resultant from the investigations undertaken by Dayron for the Government under this contract, we have concluded that the optimum means of fabricating M42 grenade bodies in high volume would be by continuous furnace-brazing a transfer-press-produced embossed dome to an embossed welded cylinder.

We have concluded that this process will produce a superior part at a much lower cost as compared with the present blank, cup and draw technique. Details of our proposed process follow:

3.1 Process Flow Chart. (See Figure Number 4 on page 66.)

This chart represents the complete sequence of operations required to fabricate either an M42 or M46 two-piece brazed body assembly. It does not contain in-process inspections, but does include Government inspection operations required to assure delivery of an acceptable and reliable product.

3.2 Process Plans. (Refer to Appendix I.)

These plans are a detailed outline of the operations and inspections required to produce the M42/M46 grenade body. References made to the embossing and annealing of the coil stock used in the dome and cylinder apply only to the M42 grenade body assembly.

A brief description of requisite production facilities is included in these plans. Facility costs are shown in Appendix II.

3.3 Body Assembly Cost Estimates. (See Figures 5 and 6 on pages 68 and 69.)

This summary chart shows the itemized costs that comprise the total estimated selling price of an M42 grenade two-piece brazed body assembly. The chart omits specific burden, G&A costs and profit figures, but provisions for these costs are included in the $.5826 final selling price.

Note: This estimated selling price is a "down-the-road" estimate which assumes amortized facility costs and stabilized labor costs.

3.4 Estimated Scrap Rate

Dome — 5.912" width x 2.160" progression (3 pieces) x .119" thick material ÷ 3 = .50654 cubic inches

.50654 cubic inches x .283333 (weight of 1 cubic inch steel) = .14352 lbs.

Cylinder — 4.830" width x 1.870" length (1.800" finished length + .030" cutoff + .040" of tube end average per piece) x .130" thick material = 1.17417 cubic inches.

1.17417 cubic inches x .283333 (weight of 1 cubic inch steel) = .332678 lbs.

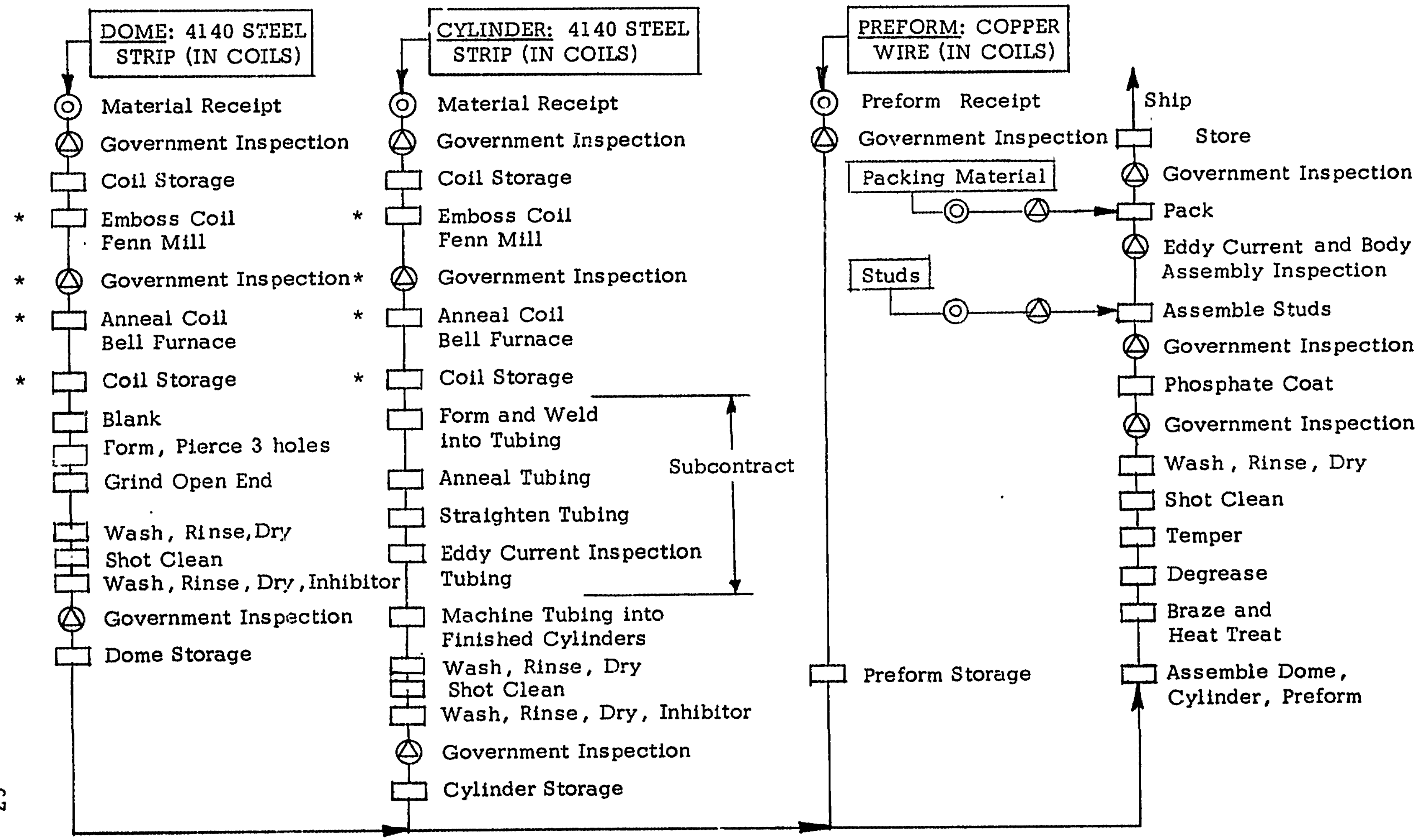
Dome total material weight .14352 lbs. + cylinder total material weight .332678 - .476198 total pounds of steel material required to produce one (1) M42 grenade body.

The material weight of the final M42 grenade body is .332 pounds. (See note below.) Grenade weight .332 lbs. ÷ total material weight .476198 lbs. = 69.7% material process yield.

Production scrap is estimated at five (5) percent, .05 x .476198 = .0238 pounds of scrap per grenade body. Considering process and production yields, .476198 + .0238 = .499998 pounds of material are required to produce one acceptable grenade body. This equates to an overall yield of 66.4% or a total material loss of 33.6%.

Note: The brazed grenade body design has a thicker and heavier (.015 pounds) dome than the current blank, cup and draw configuration. This resulted from our utilization of the present .119" embossed stock which thins out considerably during full body blank, cup and draw operations, but changes only slightly during our dome-forming operations. Should it be desirable to reduce the weight of the brazed configuration to match the blank, cup and draw design, this can be readily accomplished by employing an embossed material of .100" for the dome. The configuration requirements of the current M42 Body Drawing 9325344 will still be met and the material process yield will be unaffected.

PROCESS FLOW CHART - M42/M46 GRENADE BODY (BRAZED ASSEMBLY)



* Operations not required for M46 Grenade Body Assembly

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Figure 4

M42/M46 GRENADE BODY PRICING INFORMATION

(Rate 1,400,000 Units/Month on a 3-8-5 Basis
or 2,700 Units/Hour)

OPERATION	Labor Category	No.	*Cost/ Hour	Extended Cost
Fenn Mill (Emboss)#	Operator	1	$18.98	$18.98
Bell Furnace (Anneal) #	Setup	1	21.65	21.65
Punch Press (Dome Blank)	Operator	1	18.98	18.98
Transfer Press (Dome)	Setup	1	21.65	21.65
Blanchard	-	-	-	-
New Britain (Cylinder)	Setup	3	21.65	64.95
	Operator	3	18.98	56.94
Assembly (Dome, Cylinder, Preform)	Operator	1	18,98	18.98
Furnace System	Setup	2	21.65	43.30
Clean System	Operator	1	18.98	18.98
Phosphate System	Operator	1	18.98	18.98
Assemble Studs	Operator	1	18.98	18.98
Eddy Current and Braze Inspection	-	-	-	-
Packing	Operator	3	18.98	56.94
	Utility	1	16.39	16.39
Inspection (Patrol)	Inspector	7	15.26	106.82
Inspection (Receiving)	Inspector	1.33	18.60	24.74
				$527.26
ENGINEERING				
Mfg. (Press/Screw)	Mfg. Eng.	.333	25.58	8.52
Mfg. (Assy./Braze)	Mfg. Eng.	.333	25.58	8.52
Quality Control	Qual. Eng.	.166	23.03	3.82
Design	Design Eng.	.333	18.63	6.20
				$27.06

DIRECT MATERIAL (including G&A and Profit)	$.3773
DIRECT MFG. LABOR AND BURDEN	.1953
DIRECT ENGR. LABOR AND BURDEN	.0100
SELLING PRICE	$.5826

* COST includes direct hourly labor plus applicable burden, G&A and profit

\# Operation not required for M46

Figure 5

M42/M46 GRENADE BODY MATERIAL COSTS

DOME

5.912" width x 2.160" progression (3 pieces) x .119" thick ÷ 3 = .50654 cu. in.	
.50654 cu. in. x .283333 (weight of 1 cu. in. steel) = .14352 lbs.	
.14352 lbs. x $.3995/pound steel (Parker Steel, Toledo, Ohio) =	$.057336/dome

CYLINDER

4.830" width x 1.870" length (1.800" finished length + .030" cutoff + .040" bar end) x .130" thick = 1.17417 cu. in.	
1.17417 cu. in. x .283333 (weight of 1 cu. in. steel) = .332678 lbs.	
.332678 lbs. x $.3995/pound steel (Parker Steel, Toledo, Ohio) =	$.132905/cylinder
Fabricate Tubing: $316/ton ÷ 2,000 lbs. = $.158000/lb. x .349582 lbs./cylinder = (Babcock & Wilcox, Alliance, Ohio)	$.055234/cylinder
Subtotal	$.188139/cylinder

PREFORM

Copper wire brazing ring (purchase) (Lucas-Milhaupt, Cudahy, Wisconsin)	$.003180/ring

STUDS

$.01945 each x 2 required (Camcar, Rockford, Illinois)	$.038900/assembly

PACKING MATERIAL

Inner Carton $210/M; Partition (2 required) $300/M total; Pad (3 required) $120/M total; Barrier Bag $400/M; Over Pack $290/M; Tape/Freight/Etc. $180/M = Total $1,500/M	
$1,500/M ÷ 1,000 = $1.50/pack of 200 grenades $1.50 ÷ 200 = (Arnie Kunz Packaging, Elm Grove, Wisconsin)	$.007500/assembly
Subtotal	$.295055
5% Scrap Allowance	.014753
Total Material Cost (less G&A and profit)	$.309808

Figure 6

4. CONCLUSIONS

- A viable alternative process has been developed for the manufacture of M42 and M46 grenade bodies which is demonstrably superior to the present blank, cup and draw method of grenade fabrication. This development basically is the design of a two-piece grenade body assembly consisting of a dome and a cylinder joined by copper brazing. The cylinder is fabricated by processing embossed or plain steel strip through a tube mill and cutting it to length. The dome is fabricated from embossed or plain steel strip blanked and drawn in a transfer press or transfer die. The automatic brazing operation is combined with heat-treatment in a controlled-atmosphere furnace.

- M42 grenade body strength requirements were exceeded by a comfortable margin. There is a high probability that the M46 grenade can be replaced by the proposed brazed M42 grenade with further process refinement.

- All methods and processes used are well within the current state-of-the-art for very high-volume automated metal parts production.

- An automated high-volume production line is specified herein which is capable of the required 1.4 million units-per-month production rate on a 3-8-5 basis.

- The projected unit cost of the proposed brazed grenade body is under $.59 at the required production rate, assuming the amortization of equipment and stabilization of worker learning.

5. RECOMMENDATIONS

Based upon the background of the contemplated M483, M509 and GSRS usage of the M42/M46 grenade in extraordinarily high volume (we understand a new eight (8)-inch Navy round also is planned to submissile with this item), there is great incentive for the Government to insure that the grenade body is facilitized for future production in the most effective configuration and in the most cost-efficient manner.

To fully prove out the results of this contract, we recommend an immediate follow-on contract be let to fabricate about 50,000 two-piece brazed grenades for an accelerated test program to be conducted by ARRADCOM. A proving-ground test of that magnitude is required to prove conclusively the structural integrity of the proposed optimum grenade body configuration. These tests will also determine the practical feasibility of totally replacing the M46 grenade with the M42 configuration.

Concurrent with the implementation of this test program, we recommend firming up plans to promptly establish a pilot plant for the production of the new grenade(s). Concomitant with initial positive results from the test program, we recommend the procurement of long-lead items for the pilot plant. Full plant go-ahead would follow upon successful achievement of the test program. Both the detail planning of the pilot plant and the procurement of long-lead items should be accomplished under the auspices of a two-phase follow-on contract: Phase I - fabrication of 50,000 test grenade bodies; Phase II - implementation of the pilot plant.

OPERATIONAL SUMMARY SHEET

SUMMARY SHT REVISION LTR

PART NAME DOME, EMBOSSED   ITEM 9442   PART NO. 9327238

OPER NO	SHT REV	SHT NO	OPERATION DESCRIPTION	FINISHING PROCEDURE	MACHINE DESCRIPTION
10			Dayron/Government Inspection of Material		
20			Material Storage		
30			Emboss Material		Fenn Mill (1 required) Fenn Mfg. Company
40			Dayron/Government Inspection of Embossed Pattern		
50			Anneal Coil		Bell Furnace Sunbeam Corp.
60			Coil Storage		
70			Blank 3-out blank through die (cuts out three (3) 2.04" dia. blanks per one (1) press stroke from 5.912" wide material. Die progression 2.16")		Punch Press Minster Machine Co.
80			Form, Pierce 3 Holes 6-Station Transfer Die #1 Station: Feed blank automatically into station and perform first drawing operation. #2 Station: Redraw (to bring sides of dome up and partially form .285" radius). #3 Station: Restrike to fully form internal and external configuration. #4 Station: Pierce one .209 and two .125 holes. #5 Station: Idle (to be used for further part refinement, if required). #6 Station: Form .020" chamfer; eject finished part (outside of die).		Transfer Press Waterbury Farrel Co.

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OPERATIONAL SUMMARY SHEET

SUMMARY SHT REVISION LTR

PART NAME DOME, EMBOSSED   ITEM M42   PART NO. 9327238

OPER NO	SHT REV	SHT NO	OPERATION DESCRIPTION	FINISHING PROCEDURE	MACHINE DESCRIPTION
90			Inspection		
100			Grind Open End		Automatic Surface Grinder Blanchard Machine Co.
			Inspection		
120			Wash, Rinse, Dry		Sweco Washer
130			Shot Clean		Wheelabrator Cleaner Wheelabrator Co.
140			Wash, Rinse, Dry, Inhibitor		Sweco Washer Sweco Corp.
150			Dayron/Government Inspection		
160			Storage		

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OPERATIONAL SUMMARY SHEET

SUMMARY SHT REVISION LTR

PART NAME CYLINDER   ITEM M42   PART NO. 9327239

OPER NO	SHT REV	SHT NO	OPERATION DESCRIPTION	FINISHING PROCEDURE	MACHINE DESCRIPTION
10			Dayron/Government Inspection of Material 4140 Steel Strip in Coils 4.830" width x approximately 1,000 feet long		
20			Material Storage		
30			Emboss Material		(Use Fenn Mill from Process 9327238)
40			Dayron/Government Inspection of Embossed Pattern		
50			Anneal Coil		(Use Bell Furnace from Process 9327238)
60			Coil Storage		
70			Form and Weld Tubing		Tube Mill Abbey-Etna 3XU
80			Ultrasonic Inspection Tubing		Ultrasonic Inspection Station Magnaflux Corp.
			* Subcontract		
90			Anneal Tubing		Induction Anneal Station Rc[illegible]otron Corp.
100			Straighten Tubing		Tube Straightener Taylor-Wilson Machine Model 6.CR.4-BW
110			Eddy Current Inspection of Tubing		Eddy Current Inspection Station Magnaflux Corp.

* Included for information only. 1,400,000 units per month do not justify "in-house" operation of a tube mill as less than 4% of its capacity can be utilized.

OPERATIONAL SUMMARY SHEET

SUMMARY SHT REVISION LTR

PART NAME CYLINDER ITEM M42 PART NO. 9327239

OPER NO	SHT REV	SHT NO	OPERATION DESCRIPTION	FINISHING PROCEDURE	MACHINE DESCRIPTION
120			Machine Tubing Into Finished Cylinders Station No. — Dimension Machined 1 .030 x 45° chamfer 2 Rough-cut 1.291 dia. x .238 deep 3 1.310 dia., .560 depth, .610 depth, .008 depth, .800 depth and 30° chamfer, .003 R. Max., ⊥ B .003 4 1.335 dia., .525 depth and 45° chamfer, .003 x 45° chamfer 5 Ream 1.291" dia. 6 Cut off to 1.800" length at 1.335" I.D. end.		Six-Spindle Automatic Bar Machine Model 62 New Britain Machine Co.
130			Shot Clean		Cleaner Wheelabrator Corp.
150			Wash, Rinse, Dry, Inhibitor		Washer Sweco Corp.
160			Dayron/Government Inspection		
170			Cylinder Storage		

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OPERATIONAL SUMMARY SHEET

SUMMARY SHT REVISION LTR

PART NAME BODY, ASSEMBLY ITEM M42 PART NO. 9327240

OPER NO	SHT REV	SHT NO	OPERATION DESCRIPTION	FINISHING PROCEDURE	MACHINE DESCRIPTION
10			Dayron/Government Inspection of Copper Braze Material in Preform Configuration		
20			Preform Storage		
30			Assemble Dome, Cylinder, Preform		Automatic Assembly Machine Dayron Corporation
40			Braze, Heat Treat, Degrease, Temper		Continuous Braze and Heat Treat System Lindberg Co.
50			Shot Clean		Cleaner Wheelabrator Corp.
60			Wash, Rinse, Dry		Washer Sweco Corp.

OPERATIONAL SUMMARY SHEET

SUMMARY SHT REVISION LTR

PART NAME BODY, ASSEMBLY ITEM M42 PART NO. 9327240

OPER NO	SHT REV	SHT NO	OPERATION DESCRIPTION	FINISHING PROCEDURE	MACHINE DESCRIPTION
70			Dayron/Government Inspection		
80			Phosphate Coat		Continuous Finishing System Sweco Corp.
90			Dayron/Government Inspection (Ultrasonic for cracks and braze joint)		Ultrasonic Inspection Machine Industrial Metal Products Co.
100			Assemble Studs		Assembly Machine Kenematics Engr. Co.
110			Dayron/Government Body Assembly Inspection		
120			Pack		
130			Government Inspection		
140			Store		
150			Ship		

APPENDIX II

M42/M46 FACILITY COSTS (EQUIPMENT)

(For 1,400,000/Month 3-8-5 Production Rate)

DOME, EMBOSSED P/N 9327238

Facility Description	No. Reqd.	Total Cost	Source	Sq. Ft. Required	Parts/Hr.
FENN EMBOSSING MILL Model #081 with 75 HP Motor and Tooling (Initial)	1	$ 195,000	The Fenn Mfg. Co., Inc. Newington, Connecticut 06111	760	83,333
BELL FURNACE, Complete Setup Consisting of 1 Furnace and 3 Bases	1 (Setup)	150,000	Sunbeam Equipment Corp. Meadville, Pennsylvania 16335	1,904	12,500
PUNCH PRESS, Minster #P2-100-48 with initial tooling	1	121,457	Minster Machine Co. Minster, Ohio 45865	75	15,000
TRANSFER PRESS, Waterbury Farrel Model #300CR7 with initial tooling	1	447,000	Waterbury Farrel Co. Cheshire, Connecticut 06410	100	3,000
AUTOMATIC SURFACE GRINDER Blanchard Model #18A with initial tooling and chip separator	1	75,620	Blanchard Machine Co. Cambridge, Massachusetts 02139	140	6,500
WASHER (Custom Design) Drum wash, rinse, dry	1	37,000	Sweco Corporation	142	6,000
SHOT BLAST CLEANER Wheelabrator Tumblast Model #76D32	1	85,000	Wheelabrator-Frye Inc. Mishawaka, Indiana 46544	125	6,000
WASHER (Custom Design) Wash, rinse, dry, inhibitor	1	42,000	Sweco Corporation Florence, Kentucky	142	6,000

M42/M46 FACILITY COSTS (EQUIPMENT)

(For 1,400,000/Month 3-8-5 Production Rate)

CYLINDER, P/N 9327239

Facility Description	No. Reqd.	Total Cost	Source	Sq. Ft. Required	Parts/Hr.
FENN EMBOSSING MILL (Use Mill from Part #9327238)	-	-		-	30,534
BELL FURNACE (Use Furnace from Part #9327238	-	-		-	5,883
TUBE MILL Abbey-Etna Model 3XU	1	$ 550,000	Abbey-Etna Machine Co. Perrysburg, Ohio	Shown for information only as 1,400,000 units per month do not justify "in-house" operation of a tube mill as less than 4% of its capacity can be utilized. Tube mill capacity 200 feet per minute; 1,400,000 units per month requires only 7.5 feet per minute. These costs are not included in total equipment cost.	
ULTRASONIC INSPECTION STATION (Custom Design)	1	30,000	Magnaflux Corp. Miami, Florida		
ANNEALING FURNACE Induction Anneal Furnace (Custom Design)	1	30,000	Robotron Corp. Detroit, Michigan		
TUBE STRAIGHTENER Taylor-Wilson Model 6.CR.4-BW	1	120,000	Taylor-Wilson Mfg. Co. McKees Rocks, Pennsylvania		
EDDY CURRENT INSPECTION STATION (Custom Design)	1	40,000	Magnaflux Corp. Chicago, Illinois		
BAR MACHINE, New Britain Model #62 with chip conveyor and OSHA noise level control Tooling and saw cutoff	9	1,305,135 ($145,015 each)	New Britain Machine Co. New Britain, Connecticut	2,408 total	325 per machine
WASHER (Custom Design) Drum wash, rinse, dry	1	37,000	Sweco Corporation Florence, Kentucky	142	6,000
SHOT BLAST CLEANER Wheelabrator Tumblast Model #76D32	1	85,000	Wheelabrator-Frye, Inc. Mishawaka, Indiana 46544	125	6,000
WASHER (Custom Design) Wash, Rinse, Dry, inhibitor	1	42,000	Sweco Corporation Florence, Kentucky	142	6,000

M42/M46 FACILITY COSTS (EQUIPMENT)

(For 1,400,000/Month 3-8-5 Production Rate)

BODY, ASSEMBLY P/N 9327240

Facility Description	No. Reqd.	Total Cost	Source	Sq. Ft. Required	Parts/Hr.
ASSEMBLY MACHINE Dome, cylinder, braze, preform (Custom Design)	2	$ 300,000	Dayron Corporation Orlando, Florida	200 total	1,500 per machine
CONTINUOUS BRAZE AND HEAT TREAT SYSTEM (Custom Design)	1	240,000	Lindberg Co. Chicago, Illinois	1,200	2,700
SHOT BLAST CLEANER Wheelabrator Tumblast Model #76D32	1	85,000	Wheelabrator-Frye, Inc. Mishawaka, Indiana 46544	125	6,000
WASHER (Custom Design) Wash, rinse, dry	1	37,000	Sweco Corporation Florence, Kentucky	142	6,000
PHOSPHATE COATING LINE (Custom Design)	1	70,000	Sweco Corporation Florence, Kentucky	323	7,000
ULTRASONIC INSPECTION MACHINE (Custom Design)	1	225,000	Industrial Metal Products Co. Lansing, Michigan	80	5,000
STUD ASSEMBLY MACHINE (Custom Design	2	165,000	Kenematics Engineering Co. Janesville, Wisconsin	180 total	1,800 per machine
TOTAL FACILITY COSTS (EQUIPMENT)		$3,744,212*		8,455**	

* NOTE: Does not include installation of the above equipment nor costs for toolroom support equipment, material-handling equipment, off-line inspection equipment or exhaust systems, lighting, heating, air conditioning and other miscellaneous physical plant equipment.

** Figure represents approximately area items occupy, but does not include space for aisles, storage, material-handling access, conveyors, inspection stations, toolroom support equipment and miscellaneous physical plant equipment.